CAMBRIDGE ENGINEERING SELECTOR

Version 3.2

USER'S MANUAL

Granta Design Limited

Cambridge Engineering Selector v3.2 User's Manual
Release 1

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When referring to the *CES software* in publications, the bibliographic reference is:

> *"Cambridge Engineering Selector v3.2, Granta Design Limited, Cambridge, UK, 2001."*

When referring to this *User's Manual* in publications, the bibliographic reference is:

> *"Cebon, D. Ashby, M.F. and Lee–Shothaman, L 'Cambridge Engineering Selector v3.2 User's Manual', Release 1, Granta Design Limited, Cambridge, UK, 2001."*

PART 1
INTRODUCTION, INSTALLATION

Chapter 1 Introduction

1.1 Read this First!

The Cambridge Engineering Selector (*CES*) is a powerful tool. It has two main components: *Selector* and *Constructor.* *Selector* incorporates a set of *eight* data tables (materials, manufacturing processes, shape, structural sections, suppliers, references, uses and industrial sectors). Additional tables can be purchased separately. These tables are linked together in a relational structure to provide a powerful engineering selection system. They contain unique sets of high quality data, developed by Granta's specialist database team, in conjunction with Cambridge University Engineering Department. *Selector* contains a powerful selection methodology for choosing entities to optimise performance, based on design specifications.

It is possible to use the selection facilities of *Selector* without knowing the finer details of the selection methodology. However, you will only benefit from the full power of the package to optimise selections if you take a little time to read about it in Chapter 3 of this manual (*CES* Concepts) and in the Background Reading section of the on-line book '*CES InDepth*'. We also recommend that you read the Selector Quick Start Guide (Chapter 5 of this manual), and that you work through some of the Tutorials on how to use the package in the on-line *Help* system.

CES Constructor is a tool for making and editing selection databases for use in *Selector*. In order to work well for *optimal* selection, databases need to have a number of special characteristics. Some of the background to database design is provided in Chapter 6. The *Constructor* Quick Start Guide in Chapter 7 illustrates a number of the important features of *Constructor*, and Chapter 8 expands upon some of the more technical aspects of the package. To learn about the remaining facilities, we recommend that you work through the comprehensive set of Tutorials in the on–line *Help* system.

1.2 Organisation of the Manual

This manual contains eight Chapters:

Part 1 Introduction, Installation

Chapter 1 Introduction	provides some general information about obtaining help, using the mouse, typographical conventions in this manual, and the 'docking' toolbars in *Selector* and *Constructor*.
Chapter 2 Installation	gives step–by–step instructions on how to install single– user and multi–user copies of *CES*.

Part 2 Selection

Chapter 3 CES Concepts	explains the basic concepts and definitions underlying the organisation of *CES* databases and the selection methodology.
Chapter 4 Data Modules	describes the contents of the three core selection data tables in the *CES* system: Material, Process and Structural Sections.
Chapter 5 Selector Quick Start	provides a brief overview of the facilities of *CES* in tutorial format.

Part 3 Construction

Chapter 6 Database Design	discusses the design of selection databases: their structure and important features.
Chapter 7 Constructor Quick Start	provides tutorials on the use of some of the key features of *Constructor*.
Chapter 8 Advanced Features	discusses some of the more technical aspects of *CES Constructor*: in particular, links, data checking and importing data from external files.

1.3 Tutorials and Reference Information

A comprehensive set of tutorials on use of *Selector* and *Constructor* as well as reference information about all aspect of the software can be found in the on-line *Help* system.

The on-line book 'CES InDepth' contains a wealth of information about the *CES* system, including details of the selection methodology, definitions of all attributes in the database, 50 interactive case studies, and supporting information including solutions to many standard engineering problems, tables of equivalent material designations, etc.

1.4 Obtaining Help

Help can be obtained in *Selector* and *Constructor* in three different ways:

(i) Select the **Contents** option from the **Help** pull–down menu at the top of the CES screen.

(ii) Click on the **Help** button on the standard toolbar.

(iii) Press function key **F1** at any time to obtain context–sensitive Help.

1.5 Mouse Buttons

One click of the *left* mouse button is used for selecting objects and menu options in *Selector* and *Constructor*. Double-clicks of the left mouse button normally invoke the *default* action for a particular object. For example, double-clicking on the name of an entity in the *Selection Results* window of *Selector* presents a list of the entity's attributes.

The *right* mouse button can be used throughout *CES* to obtain 'shortcut' or 'context' menus for an object. These menus shows the most frequently used commands for that object. The first item on the context menu is often the default action (see figure 1.1 below).

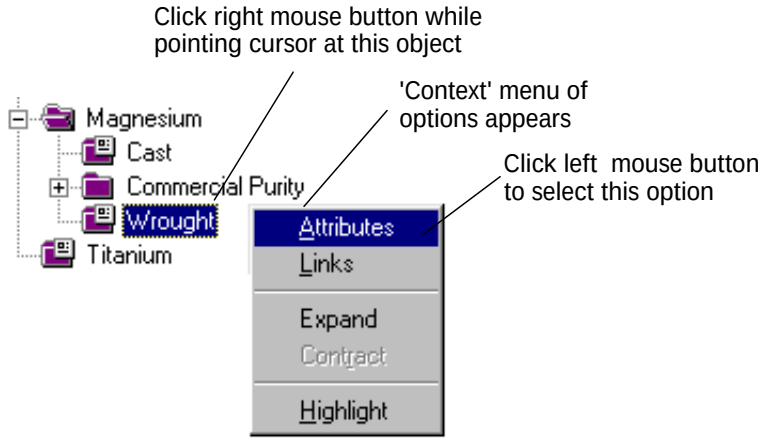


Fig. 1.1 'Shortcut' or 'Context' menu. This one was obtained by clicking the right mouse button on the Magnesium/Wrought branch of the *CES* Materials tree.

1.6 Typographical Conventions

• Instructions that you should follow in the *Installation Manual* and *Quick Start* Guides are denoted by indented text in **boldface**, such as the following line:

This is the format of an instruction

• The names of menu options and buttons in this manual appear in **boldface**.

• Sub–menus are written with forward slashes '/' separating items: '**View/Results'** means the **Results** option on the **View** menu.

• The names of windows and dialog boxes appear in italics, eg *Project* window.

• Items of text contained in list boxes appear in 'quotation marks'.

• Words and numbers that you type as you follow the instructions are underlined.

• ↵ means press ENTER.

1.7 The Toolbars

There are several 'docking' toolbars available in both *Selector* and *Constructor*. They can be switched–on and off using the **Toolbars** option on the **View** menu (**View/Toolbars**). 'Docking' means they can be moved around the screen and placed at convenient locations, by dragging them with the mouse. When a toolbar is placed against an edge of

the program viewing area (the 'frame'), it will merge into the frame. Another toolbar placed alongside will merge into the first.

If you place the cursor over a button a 'tool tip' will appear. This will give one or two words of explanation about the function of the button.

Explanations of the various buttons on the toolbars are provided in Appendix A.

1.8 What's New in *CES3.2*

This section is only relevant if you have upgraded from *CES*3.1 to 3.2. For information about the differences between the Cambridge Materials Selector (CMS) and CES, visit our web site: www.grantadesign.com/products/diffcmsces.htm.

The major additions in CES 3.2 *Selector* are the capacity for 'model-based selection', that is, selecting entities using properties which vary with one or more independent parameters (eg, variation of elastic modulus with temperature); data export to finite element analysis packages; process cost modelling, enabling selection of processes on cost criteria; substantially extended information about polymers and polymer composites; information about tool steels and magnetic properties of materials, as well as extensive information about trade names, equivalent designations, chemical compositions, and numerous other features. *CES Constructor* has been enhanced with a variety of new facilities, including sophisticated database copying and merging facilities and the Weblinks Manager system for managing linkage to web searching.

There is now also an option to have the Military Handbook data (MIL-HDBK-5 and MIL-HDBK-17) included in *CES 3.2*, making it particularly relevant to aerospace and defence industries.

The enhancements in CES 3.2 are described in detail in the following sub-sections.

1.8.1 CES Selector

Model-Based Selection.

Model-based selection is the software capability in *CES* that enables selections based on 'functional data'. Functional data describes properties that vary with one or more independent parameters eg '*Modulus* with *Temperature*' or '*Fatigue Strength* with *No. of Cycles* and *Stress Ratio*'. Model-based selection allows selections to be made through manipulation of this type of data. Example: On a chart of Density vs *Modulus with Temperature*, the user can change the specified temperature. The software automatically changes the value of Modulus for each material accordingly.

This versatile capability can be used to store many kinds of functional data e.g. creep, fatigue, deformation mechanism maps, variation of properties with temperature etc.

Export to FE Packages

An export capability to some of the major Finite Element Analysis (FE) packages has been developed. Currently data can be exported to: ABAQUS, ANSYS, NASTRAN, PATRAN.

Full Text Searching

The new search facility means that users can search across all text properties in any of the data tables in the database e.g. trade names, typical uses.

Composition Searching

A new Form, 'Composition' contains the composition details for each of the materials in the database. This can be used to select materials not just on their properties but also based on their composition. This is also fully compatible with the full text search facility (above).

Axis range – Charts

The user can now specify axes range for selection charts. Previously the axes range was fixed, at the maximum and minimum values of the displayed data.

Elongation

The property used to describe how much a material can stretch before breaking has been changed from 'ductility' to 'elongation'. The two are identical, except that elongation is expressed as percentage instead of a fraction, e.g. ductility of 0.1 equates to an elongation of 10%.

Hide Non-Applicable Properties

When viewing data sheets in *CES*, if there is no data for a particular property the message "Not Applicable" is displayed. It is now possible to hide these properties so that only properties that have values are displayed. The control for this option is in *Tools/Options* on the menu.

'All Bulk Materials' Filter

The default filter in *Selector* is now referred to as 'All Bulk Materials'. It contains all materials in *CES* with the exception of some that are considered not suitable for making engineered products. (Examples include commercially pure metals, the less common woods, reinforcement fibres, particulates, and some natural materials such as bone.) The filter 'All Materials' contains all the material records in the *CES* materials data module.

1.8.2 CES Constructor

The power of *CES Constructor* has been greatly enhanced with sophisticated software tools which enable database managers to copy and manipulate their in-house data and merge it with reference data sources.

Model-Based Selection

It is now possible to store Functional data in *CES Constructor*, either as a mathematical function or as an array of points.

New Data Types

Five new data types are available in CES databases. These are functional range, functional point, integer, date and hyperlink (URL). All except hyperlinks can be used in selections.

Expanded Table Size

The limit on the number of fields in a CES table (previously 256) has been removed. CES tables can now contain any number of fields.

CES Weblinks Manager

CES Weblinks Manager is a facility in *CES Constructor* that enables the user to edit the *Weblinks* database (a database of relevant web sites) to keep it relevant and up-to-date, and upload the database to *CES Weblinks Server*. *CES Weblinks Manager* can automatically store web site addresses (which are entered by drag and drop from a web browser) and link them to other related records in the database.

CES Weblinks Server is available for purchase separately. Please contact Granta Design for further information.

1.8.3 Materials Data Module

Polymers

The Polymer section of the materials table has been completely revised and updated. It now contains over 500 records covering filled and unfilled polymeric grades and covers the vast majority of commercially available polymers

Fifteen new polymer-related attributes have been added:

Compressive Modulus	Flexural Modulus
Hardness - Rockwell M	Hardness - Rockwell R
Linear Mould Shrinkage	Moulding Pressure Range
Processing Temp. (Compression)	Processing Temp. (Extrusion)
Processing Temp. (Injection)	Dissipation Factor
Transparency	Tradenames
Polymer Type	Filler Type
% filler	

Polymer Composites

Information for 25 polymer matrix lamina and laminate composites has been added to the data module. The properties for quasi-isotropic (QI) laminates are given for all composite materials.

Base data is included for both non-woven and woven materials. The base properties for the non-woven materials are given for unidirectional laminates in the longitudinal and transverse directions. For the woven materials, the properties for biaxial laminates are used. Where data was taken from the MIL-HDBK-17, links to MIL-HDBK-17 test data information have been added (requires the optional separate MIL-HDBK database for this to work).

Tool Steels

The materials table has been enhanced with records covering 82 Tool Steels. Additional properties appropriate for the specific properties of tool steels have been added. These properties allow the selection criteria to reflect the needs of tool tip materials. Examples

include: Decarburisation Resistance, Distortion Resistance Rating and Cracking Resistance Rating.

The new tool steel materials are shown in the 'Tool Steels' filter.

Magnetic Materials

Records for 50 hard and soft magnetic materials have been added to the materials data module. The entries are split between electromagnets (soft magnets) and permanent magnets (hard magnets). Specific properties including maximum permeability, coercive force, remnant induction and saturation induction have been added to some existing records for soft magnets. For the hard magnets, data is available for remnant induction, coercive force, intrinsic coercive force, maximum energy product and recoil permeability. In addition, details of the temperature dependence of the above properties are available for some materials.

The magnetic materials and their specific properties are shown in the 'Magnetic' filter and form.

Aluminium-Beryllium

Aluminium-Beryllium (AlBeMet) alloy has been added to the database. This is an important new material for high-end, light-stiff applications.

Trade Names and Equivalent Standards Designations

These have been extensively revised and updated in co-operation with ASM International and now cover 47 standards organisations in 40 countries. *CES* includes approximately 8,000 material equivalencies.

Fatigue Strength

A Fatigue Strength model property (known as an S-N curve) has been included for the metal records in *CES*. This is a generic fatigue model, constructed by Granta Design to estimate the fatigue strength based on the variables 'No. of Cycles' and 'Stress Ratio', the values of which can be changed by the user.

Hardness

The generic hardness property (i.e. given for all materials) has changed from 'Hardness' to 'Hardness – Vickers'. Vickers hardness is a known engineering property. The previously used hardness was a stress equivalent, effectively a factor of 10 greater.

Note: Alternative hardness systems are available for some materials where relevant, e.g. Rockwell M and R for polymers, Rockwell C for tool steels.

Transparency

All materials are now ranked on four levels of transparency: Opaque, Translucent, Transparent and Optical Quality.

The old logical property 'opaque' for ceramics has been deleted.

MIL-HDBK data

The materials module within the *CES 3.2* standard database includes records for all of the MIL-HDBK-5 materials. These records do not carry any statistical traceability and

include information from other sources. Similarly, records have also been included for generic unidirectional (UD), biaxial (BI) and quasi-isotropic (QI) laminates fabricated from composite materials from MIL-HDBK-17. These database updates allow materials contained within two major sources of aerospace specific information to be compared and contrasted with the widest range of possibilities. The original data in MIL-HDBK-5 and MIL-HDBK-17 can be accessed via separate optional *CES* tables.

Direct access to the MIL-HDBK-5 PDF files is provided for all of the appropriate materials via the *CES Weblinks* system. The links allow the exact section of a PDF file to located easily, directly from a materials record in *CES*, increasing the availability and value of this information source, as well as providing traceability information for the MIL-5 material data.

Unit Systems

Two new self-consistent Imperial unit systems have been introduced for the FE export facility. The two systems are FPS (Consistent) and IPS (Consistent). For these two unit systems all lengths are expressed in feet (ft) or inches (in) and masses in pounds (lbs).

1.8.4 Process Data Module

Cost Index

A model-based property called 'Cost Index' has been added for each of the processes in the database. This property contains a process cost model, which provides an estimate of the relative cost of making a component by the process as a function of parameters such as batch size, overhead rate and tooling cost. The cost model is a mathematical function of resource consumption.

1.8.5 Structural Sections Data Module

The data on Structural Sections, previously stored in the Shape table, has been moved to its own table.

1.8.6 MIL-HDBK Data Module

The *CES* MIL-HDBK Data module is available as a separate add-on to existing *CES* 3.2 software installations. This database contains data from the two Handbooks, MIL-HDBK-5 (Metallic Materials and Elements for Aerospace Vehicle Structure) and MIL-HDBK-17 (Composite Materials).

The MIL-HDBK-5 data is reproduced with the minimum of changes. The A, B and S basis statistical traceability is maintained. All *CES* records are linked directly with the appropriate pages in the published MIL-HDBK-5 PDF file on Granta Design's web site. This enables the relevant data sheets and sections of the handbook for each material to be located rapidly in *CES* using the *Weblinks* system.

The MIL-HDBK-17 data is stored in records for each combination of materials. The original data is available unchanged. Additional derived data records have been generated by manipulating the original raw laminae data using standard composite mechanics. These records, easily identifiable, and stored in a separate data table, have been compiled from the detailed ones by experts at Granta Design in order to allow greater value to be extracted from MIL-HDBK-17 by *CES* users.

Chapter 2 Installation

2.1 Introduction

This part of the User's Manual provides instructions for registering and installing your copy of *CES 3.2.*

2.1.1 System Requirements

In order to run *CES 3.2,* your personal computer (PC) must have the Windows™ operating system (Windows 95, 98, 2000 or Windows NT4, service pack 3 or later) and should have at least a Pentium II processor (or equivalent) with 32MB of RAM and SVGA graphics (256 colour, 800x600), mouse or compatible pointing device. A 'compact' installation of a single user licensed copy will need at least 300MB free hard disk space and 4X CD-ROM drive. A full installation will require around 400MB free hard disk space. An Internet connection is required for running *CES Weblinks.*

You may need Administrator Rights to install the software.

2.1.2 Licence Options

The *CES* Licence Agreement specifies the number of 'users' or 'seats'. This is the number of computers on which the software may be installed.

If the Licence is for a *Single User,* then the software may be installed on *one personal computer* only. Installation on more than one computer or installation on a network drive is forbidden under the terms of the Licence.

If the Licence is for *Multiple Users* (multiple 'seats') the software may be installed on the number of *computers* specified on the Licence Agreement. Note that such installations may use a network drive to store a single common copy of the database.

2.1.3 Configuration

For a single-seat licence, the program must be installed on the hard disk drive of a PC. With multiple-seat licences (eg *teaching* licence or *office* licence), the program must be installed on each PC. In network installations, this can be done using the 'netsetup' program which is supplied with the software. Each networked PC must have access to some 'writeable' file space, either on a local hard disk or on a network file server. Network installations are discussed in Section 2.5.

All *CES* data modules are installed by the installation procedure described in the following sections. Additional *CES* data modules can be purchased and installed in the same way.

2.2 Running the *Setup* Program

If you have installed a copy of *CES Selector Evaluation*, it is recommended that you un–install this before installing your licensed copy.

CES uses a *Setup* program similar to those of many other Windows™ applications. You can proceed through the stages of installation by clicking *once* with the left mouse button on the **Next** or **Yes** buttons. You can stop the installation process whenever a **Cancel** or **Exit Setup** button is displayed. A **Back** button will take you back to the previous stage.

Insert the disk in your CD-ROM drive

The Setup program should run by itself. If it does not, try one of the following actions:

Open Windows Explorer and double-click on the file Setup.exe on your CD-ROM drive

or use the Windows™ 'Run' command as follows:

From the Windows™ Start menu, select the 'Run' command

This will open the Windows™ 'Run' dialog box, as shown in figure 2.1.

Fig. 2.1 The Windows™ *Run* dialog box

Click in the Open field in the Run dialog box, then type E:\Setup

where E:\ is the location of the Setup.exe file (your CD–ROM drive).

Click once on *OK.*

If one of the above procedures has been successful, after a few seconds, you should see the Welcome dialog box (figure 2.2).

Click on the *Next* > button

2.3 Registering Your Copy of CES Selector

To register your copy of *CES Selector*, enter the relevant details for your Name, Company and registration Key (see figure 2.3). A Name is required. Your registration key is provided on the Licence Agreement card that accompanied the software.

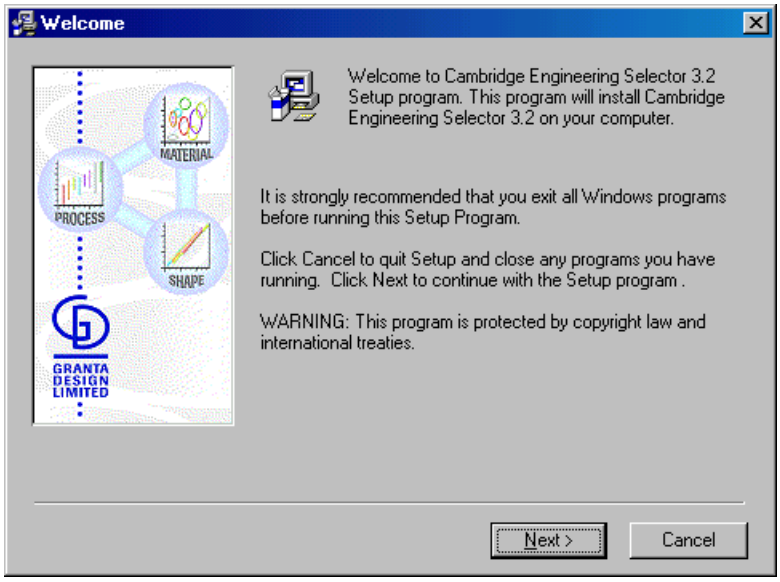

Welcome
MATERIAL
PROCESS
SHAPE
GRANTA DESIGN LIMITED
Welcome to Cambridge Engineering Selector 3.2 Setup program. This program will install Cambridge Engineering Selector 3.2 on your computer.
It is strongly recommended that you exit all Windows programs before running this Setup Program.
Click Cancel to quit Setup and close any programs you have running. Click Next to continue with the Setup program .
WARNING: This program is protected by copyright law and international treaties.
Next >
Cancel

Fig. 2.2 The Welcome dialog

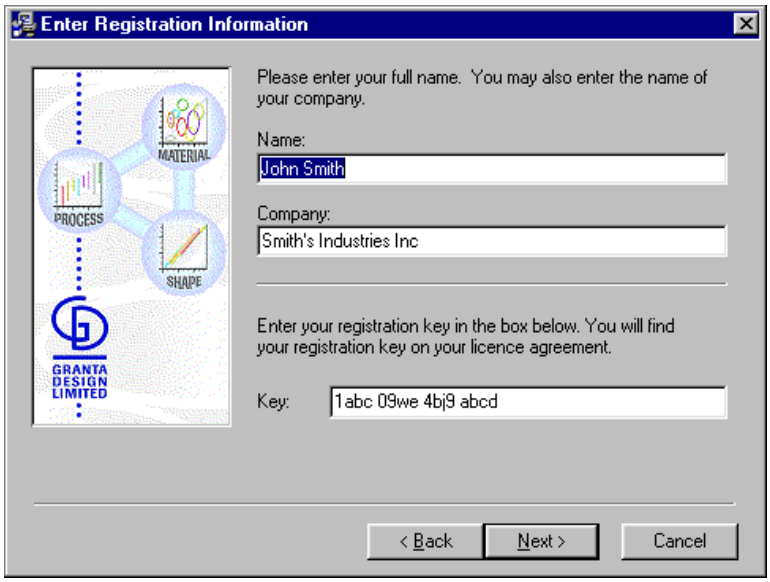


Fig. 2.3 Registration information

Enter your Name and Company details

Enter your registration key (located on your Licence Agreement card) by typing it in the field provided

Click once on *Next >* to confirm the registration information and continue with the setup procedure

The Licence Agreement screen will appear (figure 2.4). The Licence Agreement is a legally binding agreement between you and Granta Design Limited. The same Licence Agreement text appears on the Licence Card. For 'Customer' details, the 'Site' and any special conditions, please see the hard copy Licence Card.

IF YOU CLICK ON THE ***I Agree*** BUTTON, YOU AGREE TO BE BOUND BY THE TERMS OF THE LICENCE AGREEMENT AS SPECIFIED ON THE LICENCE AGREEMENT SCREEN AND ON THE LICENCE CARD.

Once you have read the licence agreement, you can proceed with installing *CES Selector*:

Click once on the *I Agree* button, if you agree to be bound by the terms of the Licence Agreement.

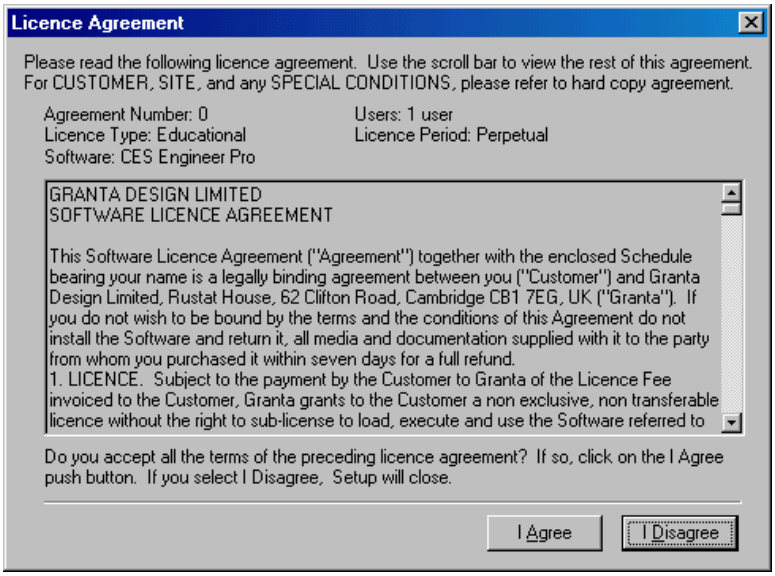

Licence Agreement
Please read the following licence agreement. Use the scroll bar to view the rest of this agreement.
For CUSTOMER, SITE, and any SPECIAL CONDITIONS, please refer to hard copy agreement.
Agreement Number: 0
Licence Type: Educational
Software: CES Engineer Pro
Users: 1 user
Licence Period: Perpetual
GRANTA DESIGN LIMITED
SOFTWARE LICENCE AGREEMENT
This Software Licence Agreement ("Agreement") together with the enclosed Schedule bearing your name is a legally binding agreement between you ("Customer") and Granta Design Limited, Rustat House, 62 Clifton Road, Cambridge CB1 7EG, UK ("Granta"). If you do not wish to be bound by the terms and the conditions of this Agreement do not install the Software and return it, all media and documentation supplied with it to the party from whom you purchased it within seven days for a full refund.
1. LICENCE. Subject to the payment by the Customer to Granta of the Licence Fee invoiced to the Customer, Granta grants to the Customer a non exclusive, non transferable licence without the right to sub-license to load, execute and use the Software referred to
Do you accept all the terms of the preceding licence agreement? If so, click on the I Agree push button. If you select I Disagree, Setup will close.
I Agree
I Disagree

Fig. 2.4 The Licence Agreement

2.4 Installation

The remaining information required for installation is the location and the software components to be installed. The default installation location is a directory called C:\Program Files\CES Selector 3.2. You do not have to create the default directory beforehand, the setup program will create it for you.

If you wish to change the destination location for your copy of *CES Selector:*

Click once on the *Browse* button on the 'Choose Destination Location' dialog box (figure 2.5). Select a folder in the 'Select Destination Directory' dialog and then click once on *OK*

When you are happy with the destination,

Click once on the *Next* > button.

The 'Select Components' dialog will appear (figure 2.6). This screen informs you about some details of your Licence (including the components that will be installed) and enables you to choose between a Full and Compact installation.

A *Full* installation will install all of the components, including the on-line books. You will use about 400 MB of hard disk space for the *CES Engineer Pro* package (less for the other packages). A *Compact* installation will install all the components needed to run *CES Selector*, but you will need to use the CD-ROM to view the on-line books. It will use about 300 MB of hard disk space for the *CES Engineer Pro* package.

We recommend that you do a Full installation if possible.

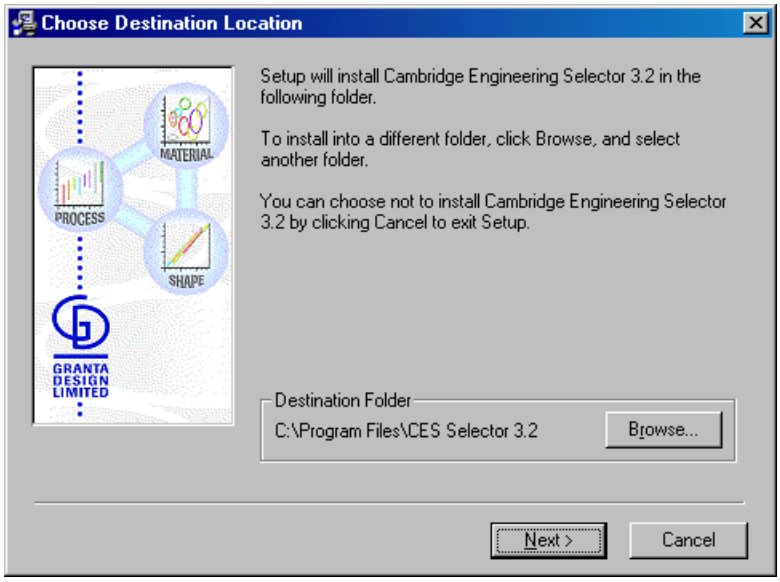

Choose Destination Location
MATERIAL
PROCESS
SHAPE
GRANTA DESIGN LIMITED
Setup will install Cambridge Engineering Selector 3.2 in the following folder.
To install into a different folder, click Browse, and select another folder.
You can choose not to install Cambridge Engineering Selector 3.2 by clicking Cancel to exit Setup.
Destination Folder
C:\Program Files\CES Selector 3.2
Browse...
Next >
Cancel

Fig. 2.5 Choose destination for software

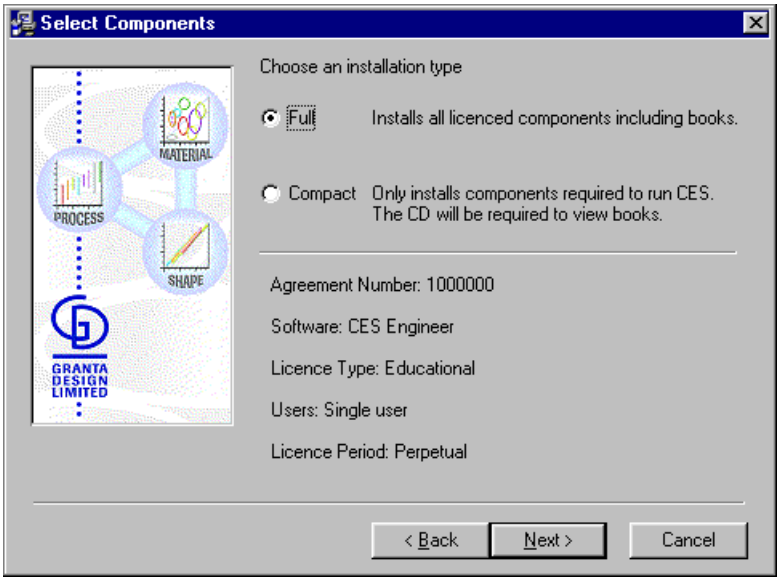


Fig. 2.6 Select installation components

Select an Installation option by clicking once on the button for 'Full' or 'Compact'

Click on the *Next >* button in this dialog box and in the following dialog box to perform the installation – or click on *< Back* if you wish to alter any of the installation settings.

A 'thermometer' indicator will inform you of the progress of the installation.

When *Setup* has finished, a dialog box will appear with the message 'Cambridge Engineering Selector has been successfully installed.'

Click on *OK* to exit the installation program.

The program will return control to Windows™.

The installation process will make a Start Menu Program group called 'CES Selector', which will contain the icons for *CES* software components, as shown in figure 2.7

Double-click on the 'CES Selector' icon to perform selections, or 'CES Constructor' to create/edit selection databases.

Uninstall the entire system by double-clicking on 'Uninstall CES Selector'

You can also access the *CES Selector* Start Menu Program group from the **Programs** option on the **Start** menu (on the Windows™ task bar).

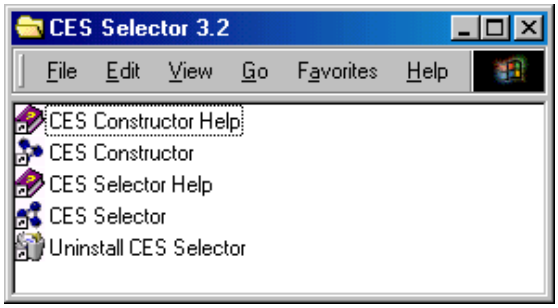


Fig. 2.7 The *CES Selector* group in Windows Program Manager

Note that the *CES Constructor* software is not automatically distributed with every *CES* system. It will only be available if you have purchased a licence for *Constructor*.

2.5 Multiple User Installations

This section provides information about options for multiple-user installations of *CES Selector*. It assumes that you have some experience with setting up Windows programs to run on networks.

Multiple–user copies of *CES Selector* can be installed in two possible ways. In both cases it is necessary to perform an installation *on every machine* on which the software is to be used.

(i) *CES Selector* can be installed individually on the hard disk drive of every machine on which it will be used, i.e. like a single-user installation. In this case, you should follow the installation instructions described in the previous sections, and install the software into a folder on the local hard disk. If more than one copy is to be used simultaneously, a 'full' installation will be required on each machine, so as to enable access to the on-line books.

(ii) The software can be installed in a folder on a network drive. In this case, you should follow the installation instructions described in the previous sections, but install the software into a folder on a network drive that is read–accessible to all PCs on the network. A 'full' installation will be required on the network drive if the users are to have access to the on-line books. The *netsetup* program can then be run on each PC on the network to install the relevant 'client' components of the software.

In both cases, users will require some file space with 'write' access, for saving *CES* output and project files.

2.5.1 Example 1

You are a commercial user and have purchased an office licence. The system administration decides to install the software individually for each user. The software is to be used on five different machines. For each machine, a Full installation to the local hard disk drive must be carried out from the CD-ROM.

2.5.2 Example 2

You are an educational user and have purchased a teaching licence. All of the 20 PCs in the lab are networked to a file server. The hard disk drive of each PC is the *'C'* drive. The network drive *'F'* can be read by the networked PCs. Only the system administrator has write access to this drive. The system administrator runs the setup program and performs a 'full' installation to the folder F:\CES Selector, and also copies the *netsetup.exe* program to the folder F:\CES Selector. Then on each of the 20 PCs in the network, the administrator runs the *netsetup.exe* program F:\CES Selector\netsetup.exe. This will install program files and dll's to the local machine, but the database and the on-line books will be accessed from the server location. A user of *CES Selector* at one of the networked PCs must have read permission for the *F* drive and write permission to a folder on the network or on PC they are currently using, for output of *CES* files (eg C:\Users).

Notes:

(i) None of the *'.exe'* files (other than the netsetup.exe) or *'.dll'* files are required in the server installation directory, unless *CES* is going to be run by a local user on the server machine.

(ii) *CES* requires certain system dll's to run. If a compatible version of these files is not found on the user's machine, and the machine is running Windows NT, then user will need to have Administrator rights to install the software – or the installation may fail.

2.6 Purchasing Additional Data Modules

Upon purchase of additional data modules, Granta Design Limited (or their accredited agent) will provide a new registration key. To install and register an additional data module, follow the instructions which come with the new module. If you have a multi-user licence and have installed to a network drive which is accessed by all the networked PCs for which you are licensed, you will only need to run the *Setup* program once.

2.7 Re–Registering your Software

If you need to re-register your software (for example, if you obtain a new licence for an extended time period or different number of users), use the **Licence Key** option on the *Tools* menu of *CES Selector or CES Constructor* to open the **Licence Key** dialog. Simply enter the new key in the input field provided.

PART 2
SELECTION

Chapter 3 CES Selector Concepts

3.1 Architecture

The *CES* system is a linked set of modules, as shown in figure 3.1. The selection is design-led, meaning that the inputs are the design requirements. These are translated into a prescription for selecting material and process properties.

CES Selector is the central module of the *CES* system. It enables engineers to select, from relational databases, a small subset of entities which optimally satisfy the requirements of a design. The selections may be performed using the *CES* materials, manufacturing processes or structural sections data modules. Alternatively they may be performed on user-databases developed with *CES Constructor*.

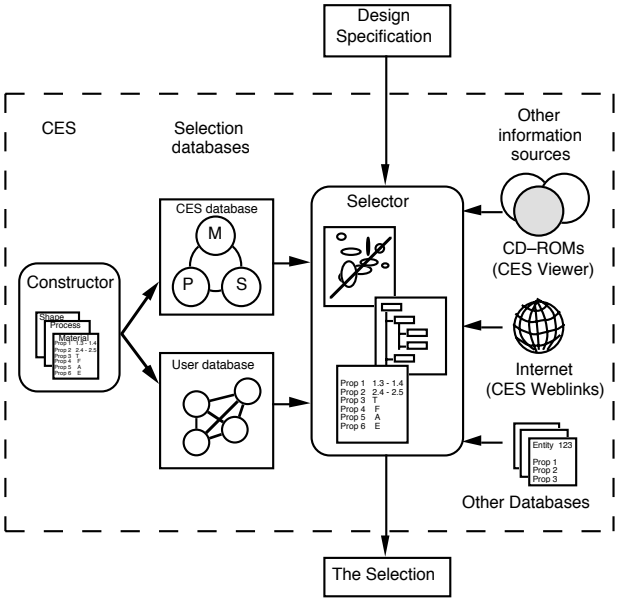


Fig. 3.1 Architecture of the *CES* System

3.1.1 Screening and Ranking

CES Selector treats *all* members of the databases as potential candidates until, by screening, they are shown to be unsuitable. As a consequence, viable candidates cannot be overlooked. This screening can be based on simple go/no-go criteria: has the material a sufficiently large modulus? Is the process able to cope with that material? More revealing, often, is to create a sequence of selection charts which give a visual picture of the important attributes of the material or process. Often it is not a single property that counts; rather, it is some combination of them. The *Selector* creates any combination of

properties you wish and allows you to screen and rank the candidates with them. *CES Selector* provides a number of other tools to facilitate sophisticated optimisation strategies, and it automatically keeps track of the selection results.

3.1.2 Supporting Information

Screening and ranking based on numeric properties are merely the first steps in any selection exercise. They deliver a ranked list of potential candidates, but this can be long, and with many questions unanswered. Once a subset of entities is found, *CES Selector* provides automatic access to vast sources of *supporting information*: searchable files or databases provided by Granta or others on CD-ROM; text, images and tabular data of the sort found in handbooks; and immediate Internet access to an enormous range of material and process information through the *CES Weblinks* system. This gives background reference information for the short-listed candidates: their reputation; case histories of their uses; warnings about their weaknesses; the environmental consequences of their use, supplier data, etc. This supporting information can be used to narrow–down the short list of candidates to a final choice.

3.2 Database Concepts

3.2.1 Database

In *CES*, a database consists of one or more *tables* (datasets) which are linked together.

The complete *CES* database has eight linked tables, as shown in figure 3.2. The main selection tables contain *materials*, manufacturing *processes*, and *structural sections*. The supporting tables contain information about *suppliers*, *references* (the sources of information that were used to compile the main tables), as well as *shape* (used in process selection), *uses* of materials and *application areas*. The main selection tables are detailed in Chapter 4 of this User's manual.

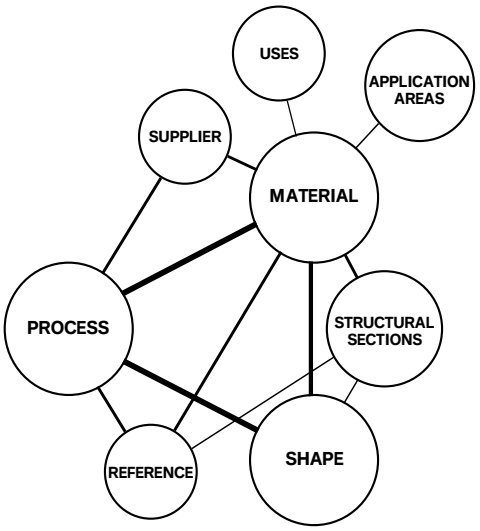


Fig. 3.2 C*ES* database structure. The circles represents tables. The lines joining tables represent links.

3.2.2 Tables

A *Table* is a compilation of information relevant to a single type of entities (records). For example, it may contain materials and their properties, or manufacturing processes. A table can be thought of as one page of a spread sheet: with records (eg materials) in each row and a set of attributes (sometimes called properties, or 'fields') in the columns.

Each table in the current database is listed in the drop-down list on the *Tables* tab in the *Project* window of *CES* (figure 3.3). The records in each table are arranged into a hierarchical 'classification tree' structure. Select the name of a table from the list to view its tree.

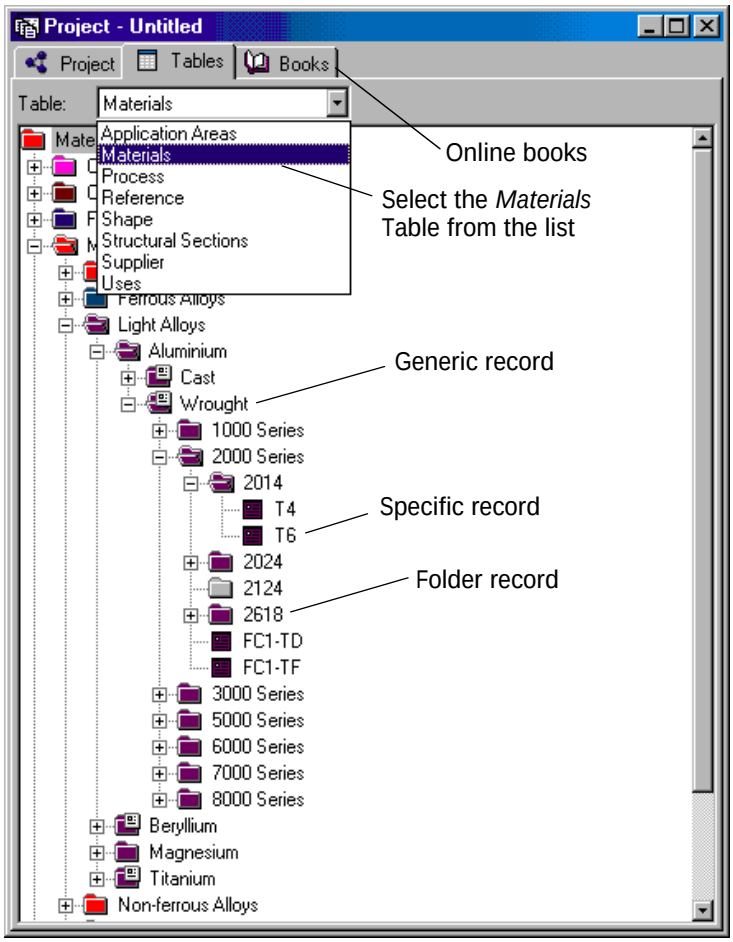


Fig. 3.3 The *Project* Window, showing the Materials table and part of the materials classification tree.

CES Selector v3.2 can only perform selections on *one table at a time* – for example materials or processes. This table is called the *Selection Table.* The Selection Table is set for the current *CES* 'Project'. If you change selection table, you must start a new project.

3.2.3 Records and Attributes

Each record in the database represents an entity – a material, a process, a supplier, etc.

Each record has a set of *attributes*. For a material record, these attributes include its composition, strength, density etc. For a manufacturing process record, the attributes include the surface finish, tolerance, economic batch size etc. For a supplier, the attributes are the Company name, address, telephone number, etc.

The attributes of a record can be viewed in the *Attributes* window (see figure 3.4).

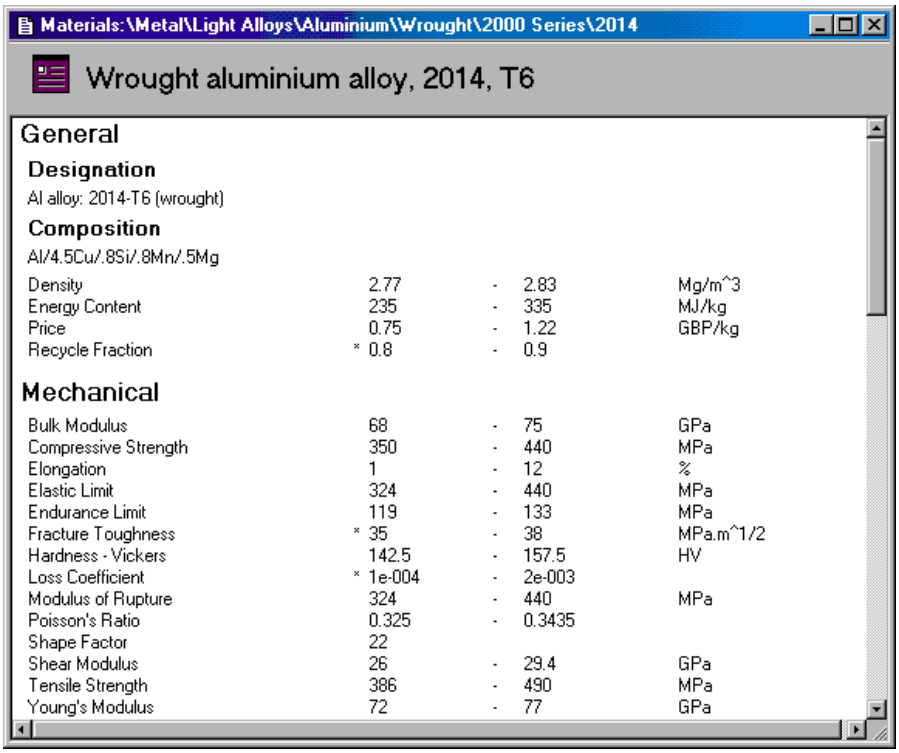

Materials:\Metal\Light Alloys\Aluminium\Wrought\2000 Series\2014
Wrought aluminium alloy, 2014, T6
General
Designation
Al alloy: 2014-T6 (wrought)
Composition
Al/4.5Cu/.8Si/.8Mn/.5Mg
Density 2.77 - 2.83 Mg/m^3
Energy Content 235 - 335 MJ/kg
Price 0.75 - 1.22 GBP/kg
Recycle Fraction * 0.8 - 0.9
Mechanical
Bulk Modulus 68 - 75 GPa
Compressive Strength 350 - 440 MPa
Elongation 1 - 12 %
Elastic Limit 324 - 440 MPa
Endurance Limit 119 - 133 MPa
Fracture Toughness * 35 - 38 MPa.m^1/2
Hardness - Vickers 142.5 - 157.5 HV
Loss Coefficient * 1e-004 - 2e-003
Modulus of Rupture 324 - 440 MPa
Poisson's Ratio 0.325 - 0.3435
Shape Factor 22
Shear Modulus 26 - 29.4 GPa
Tensile Strength 386 - 490 MPa
Young's Modulus 72 - 77 GPa

Fig. 3.4 The *Attributes* window, showing some properties of the record Aluminium Alloy 2014–T6.

3.2.4 Folders

Every record in the database has a unique 'Identifier' (ID), which is used to distinguish it from all other records. The records are organised into a hierarchical 'tree' structure, known as an 'identifier tree' or 'table tree'. Individual records are the 'leaves' of the table tree. Part of the Materials Table tree can be seen in figure 3.3.

A *folder record* acts as a branch of the tree. It does not have any attribute data associated with it, but does have records 'below' it in the tree.

A *generic record* is a record whose attributes span the range of attributes of a number of specific records. It is a 'fictitious' entity that represents the properties of the records below it in the tree (eg 'Wrought Aluminium Alloys' in figure 3.3). Generic records are

particularly useful during the early stages of the selection, where breadth of information, and not detail is important.

A *specific record* represents a 'real' entity (eg Aluminium alloy 2014–T4). It is not usually possible to subdivide a specific.

3.2.5 Record Identifiers

Record Identifiers consist of several pairs of letters (sometimes including blanks '–'). The first character of the identifier indicates which table it belongs to (M means Materials, P means Process etc). Subsequent letters denote the family, class and sub–class, followed by three numbers which denote the particular member of the sub–class. The same type of Table tree classification system is common to all *CES* data tables.

Part of the table tree for Aluminium Alloys is shown in figure 3.3. The identifier 'MMLAALW–SB001' can be 'decoded' as follows:

MM	Material, Metal
LA	Light Alloy
AL	Aluminium
W–	Wrought alloys
SB	2000 series
001	2000 series alloy number 001 in the *CES* designation system.

See *CES InDepth* for details of the identifier trees in each data table.

3.2.6 Filters

A *Filter* is a device for specifying which records in a table are *visible*.

The current record filter for each table can be viewed and set in the *Table Properties* dialog. The filter for the current *Selection Table* is visible on the *Filters* toolbar (figure 3.5).

Fig. 3.5 The *Filters* toolbar, showing the form and filter set for the *Selection Table*.

A set of pre-defined filters is available for each table, and is available in a list box wherever the filter setting can be changed. It is also possible to 'expand' and 'contract' generic records, so as to add or remove records from the current filter. In this case, the filter automatically becomes called '<User Defined>'.

The record filter for the *Selection Table* determines which records are available for selection.

3.2.7 Forms

A form is a template that specifies the attributes that are visible and their layout in the *Attributes* window.

Some attributes are relevant to all entities in the table, others are specific to a particular class of entities. For example 'Density' is a relevant attribute for all material records, whereas 'Water Absorption' is only relevant for a particular class of materials: Polymers.

The 'Generic' Form, (which is the default form for the Materials table, and is relevant for all classes of materials), contains Density, but not Water Absorption. The 'Polymers' form contains both Density and Water Absorption.

A set of pre-defined forms is available for each table in a list box wherever the form setting can be changed. The current form for each table can be viewed and changed in the *Table Properties* dialog. The form for the *Selection table* is also visible on the Filters toolbar (figure 3.5).

The record form for the *Selection Table* also determines the attributes that are available for selection purposes. Following the example above, it is only possible to use 'Water Absorption' as a selection criterion if the current Form is set to Polymers.

Forms can only be designed or modified in *CES Constructor* (not in *CES Selector*).

3.3 Types of Data

Each record has a number of attributes that are stored in fields in the database. The attribute data can be one of the following types. (See details in Appendix C2).

3.3.1 Numerical data

Numerical attributes can be stored as a range, a point or an integeror as functional data.

Range, Point and Integer

For attributes stored as a range, a minimum and maximum value is specified. For example, in the materials data table, Wrought Aluminium Alloy 2014–T6 has an 'Elastic Limit' in the range 350–440 MPa (figure 3.4). For attributes stored as point values, only one value is specified. All values are stored to a maximum of 6 significant figures. Point data can also be stored as integer values, using the 'integer' attribute type.

Functional range, Functional point

Functional data describes properties that vary with one or more independent parameters (see paragraph 3.3.9). The function can either be a mathematical formula or a set of discrete data points e.g. (x, y, z). *Selector* evaluates the function at user-specified values of the *parameters*. For example: On a selection chart of *Young's Modulus with Temperature* vs Density, the software interpolates a value the modulus at a user–specified temperature, from an array of data points.

There are two versions of functional data: functional range, which evaluates to a range attribute and functional point, which evaluates to a point.

3.3.2 Discrete data

Discrete attributes are those where the attribute takes one of a set of discrete values. The values can be 'A, B, C, D, E' or '1, 2, 3' or 'Red, Green, Blue' etc. For example the Environmental Resistance (resistance to standard operating environments) in the materials data module, takes a value on the five–point scale: 'Very Poor', 'Poor', 'Average', 'Good', or 'Very Good', ('Very Good' means highly resistant to the environment, and 'Very Poor' means completely un–resistant or unstable.)

The record Identifier (branch of the table tree), can also be considered conceptually as a discrete attribute for selection purposes.

3.3.3 Logical data

Logical or Boolean attributes are those that are either 'True' or 'False' (or Yes/No). For example an attribute in the process data module indicates whether a process class is 'Primary' (True) or not (False).

3.3.4 Links

Links between data tables can be considered to be attributes. For example, records in the Materials data module are linked to records in the Process module.

3.3.5 Text data

Text is stored in fields that can take a short or long string of text. They are used for qualitative data. For example the attribute 'Typical Uses' in the materials data table is of type 'long text'.

3.3.6 Picture data

Picture attributes allow the viewing of a diagram or photograph in a record, for example the 'Process Schematic' attribute in the process data table.

3.3.7 Dates

The *date* data type can be used to store calendar dates.

3.3.8 Hyperlinks

The Hyperlink data type provides a mechanism for storing URL's (Uniform Resource Locators), consisting of a protocol and location e.g. 'http://www.grantadesign.com' Clicking on the hyperlink in a record in *Selector* causes the program to open your web browser and jump to that web page. For example, a material supplier record could have a dynamic link to the supplier's web site.

3.3.9 Parameters and Constants

'Parameters' and 'Constants' are not attributes of database records, however they require definition.

Parameters

Parameters are the independent variables used to evaluate functional data. For example the *functional attribute* 'Young's Modulus with Temperature' contains values of the Young's modulus of materials as a function of the *parameter* 'Temperature'. Each parameter has a *default* value, which is stored in the database.

The *default parameters* are 'global' to a *CES* project. Their values can be changed, but the changes have a global effect.

There are two different options for setting the parameter values used to evaluate a functional attribute – eg when viewing a particular record, or when performing a selection stage:

(i) The parameter values can be set ('locally') for the particular instance of the function.

(ii) The ('global') *project default* parameters can be used for viewing the function. If the *project default* parameters are used for a selection stage, and the default parameter values are changed at any time in the current project, the selection stage will automatically update itself. For example, it would be possible to set the project default parameter *Temperature* to a value of (say) 500K (degrees Kelvin). All material selection stages which used *default* parameters in functional data would then be evaluated at 500K. If the value of this default parameter was changed, then all selection stages which used it would automatically be updated to the new temperature.

Constants

Constants are numbers like the *General Gas Constant*, the *Acceleration due to gravity*, g, or π. They can be used in *Selector* as part of a user–defined property when plotting a selection chart, or they can be used in *Constructor* as part of a checking correlation equation or functional data expression.

3.4 Data Types in Selections

CES can perform selections on Numerical (Static or Functional), Discrete, Logical and Date data types, and on Links between tables. An example of the last would be to select Materials which can be manufactured by Injection Moulding. 'Injection Moulding' is a record in the Process table. Selections cannot be performed on Text, Pictures or URLs.

3.5 Sources of Data

Where possible, information for the attributes in the *CES* databases was obtained from published literature: journals, handbooks, manufacturers leaflets or electronic sources such as databases or the World Wide Web. These sources of information are listed in the *CES References* table.

3.6 Estimated and Not-Applicable Attributes

Not all attributes can be obtained from published sources. Some may not even have been measured. It is important for the operation of *Selector* that the database is complete – has no holes or gaps (see Chapter 6 for discussion). Therefore in some places it is necessary to use expert estimates of data values. The data values, which are 'estimated', are denoted in the list of attributes with an asterisk '*'.

One such example is the attribute 'Recycle Fraction' in the 'General' attributes of Aluminium Alloy 2014–T6, shown in figure 3.4. This attribute is defined as the estimated fraction of a typical production that could reasonably be recycled (even though it may not be recycled to this extent at present) – see *CES InDepth* for definitions of attributes.

Some attributes are not relevant for some records. These are shown as 'Not Applicable' in the attribute listing. For example the 'Dielectric Constant' is shown as 'Not

Applicable' for all electrical conductors, since the dielectric constant is a property that is only relevant for electrical insulators.

By default, records with 'Not Applicable' data *fail* any selection stages based on that attribute. (This setting can be over-ridden using the *Stage Properties* dialog for a selection stage. However this is not generally recommended.)

3.7 Selection Methodology

The selection methodology behind *CES* Selector is described in the on-line book *CES InDepth* 'Background on Selection Systems'. The application of this methodology to a specific area (eg the selection of the optimum material for an engineering component) is dealt with in the section of *CES InDepth* for the relevant data module.

3.7.1 Selection Table

Before any selection can be performed, the user must specify which of the data tables will be the *Selection Table* (e.g. Materials, Process etc). This is done in the *Project Settings* dialog box (or on the *Welcome* screen when *CES* is first opened). Only one table can be used for selection in a given project. The filter and form for each data table must also be specified. The recommended filter and form combination for each type of selection is listed in Appendix B.

3.7.2 Selection Stages

Selecting records with *Selector* involves performing a series of independent selection 'stages'. On each stage, the user selects a subset of records. Every record in the current filter for the *Selection Table* is considered during each stage, and the program automatically keeps track of all the results.

One way to perform a selection is to use a Selection Chart. The two axes of a selection chart specify record attributes. The user selects the area of the chart that fulfils the selection criteria. One selection chart is used for each selection stage.

A second way to perform a selection is to use a 'Limit' stage, in which numerical limits for one or more attributes are entered in a table. Limit stages can be combined with graphical stages (using selection charts).

A single functional requirement (eg the strength/density ratio of a material) can be represented by one stage in *Selector*. In many design situations it is necessary to identify records that satisfy several functional requirements simultaneously, for example high strength/density, high stiffness and low cost/kg for a material. In these cases *Selector* can perform several selection stages and the program will store the results of each stage automatically. The selection stages can be modified at any time if necessary. At the end of the selection (or at any other time), the user can find out which records passed all, or some of the selection stages.

It is important to realise that in this strategy, all records contained in the selection table with applicable data entries are considered in every selection stage (and are plotted on the charts). Therefore each stage is independent of the others. This means that records are never discarded from the selection process, even though they may fail a particular selection stage. So it is possible to find out how every entity performed on each of the stages. The ones that pass all stages will probably be the best choices.

Selector can also generate plots of 'user-defined' attributes, which are mathematical combinations of the attributes in the database. Examples are the specific strength σ_{el} / ρ (σ_{el} is the 'elastic limit' and ρ is the density), and the performance index for a light stiff beam $E^{1/2} / \rho$ (E is the Young's Modulus). This facility greatly expands the versatility of the selection process and enables two complex performance requirements to be compared on one selection chart.

3.7.3 Types of Selection Chart

Any combination of numerical, discrete, logical and link attributes can be plotted on selection charts. This leads to three different types of charts, according to the combination of attributes used for the graph axes.

(i) Bubble Charts: are charts with two 'Numerical' axes. They are known as 'bubble charts' because the range of attributes on each axis is represented by a 'bubble' (an ellipse).

(ii) Bar Charts: arise from plotting one 'Numerical' against one 'Discrete/Logical/Link' attribute, or one 'Numerical' axis on its own.

(iii) Count Charts (or 'tables') are charts with two 'Discrete/Logical/Link' axes or one 'Discrete/Logical/Link' axis on its own. Each record fits into one or more cells of the table.

On all selection charts it is possible to select a subset of records using a 'box' tool to define the selection area. On bubble charts it is also possible to use a 'line' tool to define a subset: all records to one side of the line pass the selection.

3.7.4 Project Files

The operation of *CES3.2* is based on 'Project' files. These files contain the *CES* user's work. They are conceptually equivalent to documents in a word processor.

When a Project file is saved, it stores the current status of the *CES* session, including the selection stages in use, selection criteria, graph formats, graph labels and so on. A project file can be read into *CES* later, to re-set the program to its state when the Project file was saved.

Only one Project file can be open at a time in *CES3.2*[1].

---

[1] CMS2 project files cannot be read by *CES3*

Chapter 4 Data Modules

4.1 Materials

4.1.1 Introduction

The *CES Materials Data Module* contains data for approximately 3660 engineering materials, characterising all known classes. The data allows material properties to be retrieved quickly and efficiently, and the sophisticated selection tools in the *CES* system enable optimised selection of materials to meet a given set of design requirements.

4.1.2 Contents of the Materials Data Table.

Figure 4.1 shows the taxonomy of the Materials Data Table[2]. The 'kingdom' of Materials contains six broad 'families': ceramics, metals, polymers, composites, foams, and natural materials. Each family is made up of 'classes' (aluminium alloys, for example) and 'sub-classes' (2000 series Al alloys), consisting of many 'members' (2024 T6, for instance). Each member is characterised by a set of 'attributes': its density, its mechanical, thermal and electrical properties, its behaviour in various environments, its ability to be formed, joined and finished.

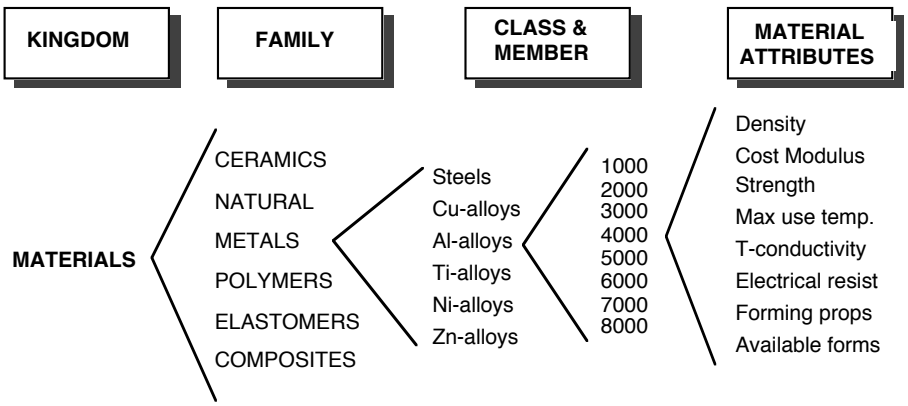


Fig. 4.1 Taxonomy of the *Materials* Data Table

The *CES* Materials Data Table presents this information for all its members. Section 4.1.3 presents a typical record, in this case for a ceramic: a cold-pressed and sintered alumina with a porosity of 3%. Every attribute is described by a range spanning its spread. All the records are complete. Where data are not available, sophisticated

[2] The Materials data *Module* consists of the Materials *Table* (which contains the property data) plus a number of other resources: information in the on–line books, filters, forms, case studies, and so on.

estimation methods are used to bracket them, allowing design concepts to be explored even when data are sparse. Each material record is linked to records in other *CES* data tables: Application Areas; Process; Reference; Shape; Structural Sections, Suppliers and Uses. These links can be used as part of the selection process. For example, you could choose materials which could be formed by a particular process using the links to the Process table.

The use of the Materials Data Table to select the best material for a particular application is best understood by looking at a case study. The on-line documentation system, *CES InDepth* contains 33 fully–worked, interactive case studies on materials selection for mechanical, electro-mechanical and thermo-mechanical applications.

4.1.3 A Typical Record in the Materials Data Table

Name	Alumina (97) (cold pressed and sintered) (MCT_AO013)			
General				
Designation	97AL2O3			
Composition	AL2O3			
Density	3.76	-	3.84	Mg/m^3
Energy Content	*150	-	200	MJ/kg
Price	*8.8	-	13.2	GBP/kg
Recycle Fraction	0			
Mechanical				
Bulk Modulus	*277	-	299	GPa
Compressive Strength	2217	-	2450	MPa
Elongation	0			%
Elastic Limit	*221.7	-	245	MPa
Endurance Limit	*188.8	-	220.2	MPa
Fracture Toughness	4.3	-	4.7	MPa.m^1/2
Hardness	1400	-	1540	HV
Loss Coefficient	*1.00E-5	-	2.00E-5	
Modulus of Rupture	266	-	294	MPa
Poisson's Ratio	0.275	-	0.315	
Shape Factor	15			
Shear Modulus	132	-	138	GPa
Tensile Strength	221.7	-	245	MPa
Young's Modulus	341	-	368	GPa
Thermal				
Maximum Service Temperature	1710	-	1780	K
Melting Point	2277	-	2369	K
Minimum Service Temperature	0			K
Specific Heat	745	-	775	J/kg.K
Thermal Conductivity	26.9	-	29.1	W/m.K
Thermal Expansion	6.4	-	6.6	µstrain/K
Electrical				
Breakdown Potential	*24	-	34	10^6 V/m
Dielectric Constant	9.5	-	10.3	
Resistivity	9.48E+21	-	9.48E+23	µohm.cm
Power Factor	0.0014	-	0.0022	

Optical	
Transparency	Opaque
Environment	
Flammability	Very Good
Fresh Water	Very Good
Organic Solvents	Very Good
Oxidation at 500°C	Very Good
Sea Water	Very Good
Strong Acid	Very Good
Strong Alkalis	Very Good
UV	Very Good
Wear	Very Good
Weak Acid	Very Good
Weak Alkalis	Very Good
Typical Uses	
Metalising of Molymanganese	
Reference Sources	
Data compiled from multiple sources. See links to the References table.	
Links	
Application Areas	
Reference	
Shape	
Structural Sections	
Process	
Supplier	
Uses	
No warranty is given for the accuracy of this data. Values marked * are estimates	

4.2 Manufacturing Processes

4.2.1 Introduction

The economics of manufacturing depend critically on the choice of processes. The *CES Process Data Table* guides this choice. It contains detailed information for 125 processes, and allows systematic selection of the most appropriate process to make a given component. The selection is based on design specifications: the component size, its shape, the material in which it is to made, the required precision and finish, and on economic criteria such as the planned production volume.

4.2.2 Contents of the Process Data Table

A *process* is a method for shaping, finishing or joining a material. The *kingdom* of processes (Figure 4.2) contains broad *families*: casting, deformation, moulding, compaction of powders and such like. Each family contains many *classes*: casting contains sand-casting, die-casting, and investment casting for instance. These in turn have many *members*: there are many variants of sand-casting, some specialised to give greater precision, others modified to allow size or adapted to deal with specific materials.

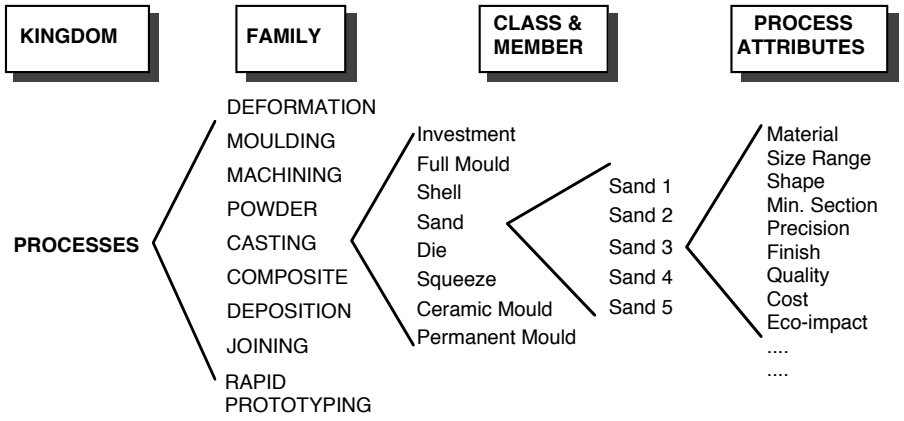


Fig. 4.2 Taxonomy of the *Process* Data Table

Each member is characterised by a set of *attributes*. It has *material attributes*: the particular subset of materials to which it can be applied. It has *shape-creating attributes*: the classes of shapes it can make. It has *physical attributes* which relate to the size, shape, precision, finish and quality of its product. It has attributes which relate to the *economics* of its use: its capital cost and running cost, the speed with which it can be set up and operated, the efficiency of material usage and the economic batch size.

Section 4.2.3 presents a typical record from the Process Table: it is for 'large scale electro-forming'. A schematic illustrates how the process works; it is supported by a short description. This is followed by a listing of attributes. All the numeric attributes are stored as ranges indicating the range of capability of the process.

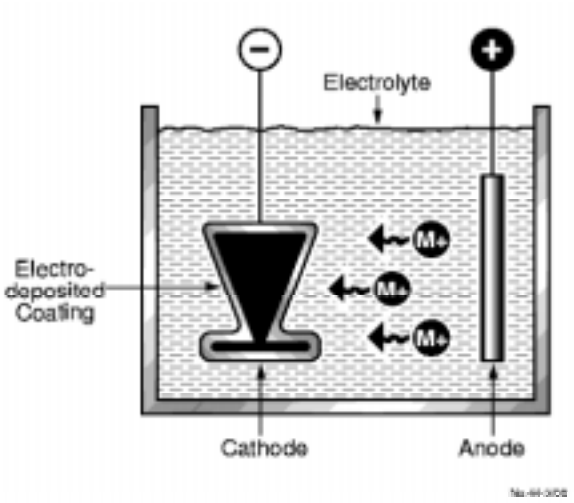
Links to the Material and Shape data tables enable selection of processes on the basis of the materials they can form and the shapes they can produce. Links to the References table provides sources of data and further information: essential in reaching a final selection.

Every process in the data table is characterised by a record like this one. The way in which the data is used to make a selection is best understood by looking at a case study. The on-line documentation system, *CES InDepth*, contains thirteen fully–worked, interactive case studies on process selection. These include components such as a manifold jacket, a spark plug insulator, a car bumper, etc.

4.2.3 A Typical Record in the Process Data Table

Name	Electroforming (large-scale)
General	
Designation	Deposition: Electroforming (large scale)
Tradename	

Process Schematic



Description of Process

ELECTROFORMING is a variation of electroplating in which metal is deposited on a mandrel which is then removed, the coating becoming the product. It is particularly useful for making parts which are difficult to make by other methods and also for forming parts which require intricate design on inside surfaces. It is capable of making intricate shapes with undercuts, re-entrant angles and fine detail. The process has some drawbacks: it is expensive – production rates are very slow and high skill levels are required, and the materials are limited to nickel and copper. On the other hand, it can achieve extremely high dimensional accuracy, excellent control over properties, and there is practically no size limitation.

Physical Attributes

Mass range (extreme)	1	-	270	kg
Mass range (normal)	1	-	20	kg
Section (extreme)	1	-	15	mm
Section (normal)	1	-	10	mm
Roughness (extreme)	0.1	-	6.4	µm
Roughness (normal)	0.4	-	6.4	µm
Tolerance (extreme)	0.05	-	0.2	mm
Tolerance (normal)	0.08	-	0.2	mm
Aspect ratio	1	-	100	
Adjacent section ratio	1	-	1.3	
Hole diameter	5	-	100	mm
Min. corner radius	1	-	100	mm
Max. dimension	1.00E+3	-	2.00E+3	mm
Quality factor (1-10)	1	-	9	

Economic Attributes				
Economic batch size (units)	1	-	1.00E+3	
Economic batch size (mass)	1	-	1.00E+3	kg
Capital cost	2.00E+4	-	8.00E+4	GBP
Tooling cost	500	-	4.00E+3	GBP
Lead time	1	-	3	weeks
Material utilisation fraction (0-1)	0.5	-	0.9	
Production rate (units)	0.05	-	0.5	/hr
Production rate (mass)	0.5	-	5	kg/hr
Tool life (units)	1	-	1.00E+3	
Tool life (mass)	10	-	1.00E+3	kg

Environmental Information

Hazardous air contamination from release of bath electrolyte from the formation of bubbles. Exhaust systems/hoods/foams can be used effectively.

Process Information

DISCRETE
P (PRIMARY)

Shape Notes

Intricate parts with very fine detail and undercuts, re-entrant angles, and reverse tapers possible.

Typical uses

Moulds for phonograph records, paint masks, wave-guides, nose cones, fountain pen parts, surface finish standards, reflectors, venturi nozzles and rocket thrust chambers.

Material notes

Mainly used for copper and nickel, with possible alternatives of gold and silver.

Links

Reference
Shape
Materials
Supplier

* Indicates estimated attributes

4.3 Structural Sections

4.3.1 Introduction

Materials that are used to carry loads in mechanical and civil structures are manufactured in a wide range of *standard-section shapes.* The *CES Structural Sections Data Table* enables selection of the best combination of material and shape to meet a given design requirement. It contains data for approximately 1900 standard cross-sections in steel, aluminium alloy, glass-reinforced polyester (GFRP) and wood. The selection proceeds by the user specifying the required stiffness and strength for axial loading, bending, or torsion, and any required dimensions. The selector delivers the standard sections and materials capable of meeting the specification, ranked by cost, by weight or by volume.

4.3.2 Contents of the Structural Sections Data Table

Figure 4.3 shows the taxonomy of the Structural Sections Data table. The *kingdom* of Prismatic Sections is arranged into broad *families*: solid sections (containing *classes* of rods and cylinders), closed hollow sections (tubes and box-sections) and open sections (I-sections, hollow rectangular sections, angle sections, channel sections, and T sections). All the categories are subdivided according to *material*: aluminium alloy, structural steel, GFRP and wood. Each *member* of a given material and shape class has a set of attributes: its dimensions; its section properties for axial, bending and torsional loading (moments of area, section moduli, fully-plastic moduli); its structural properties (properties such as EI where E is Young's modulus and I is the second moment of area of the cross-section); and properties such as cost and mass per unit length.

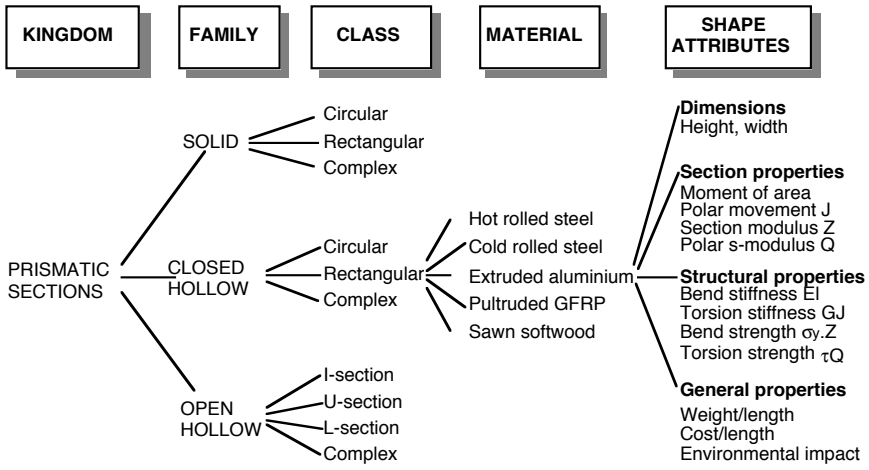
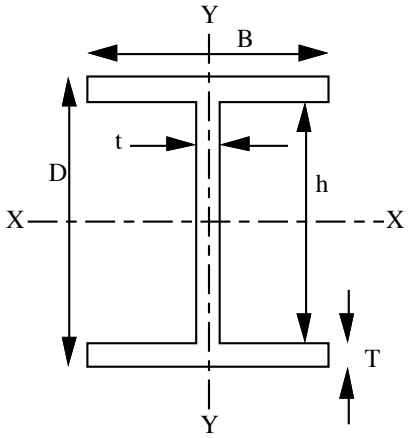


Fig. 4.3 The Taxonomy of the *Structural Sections* Data Table

Section 4.3.3 shows a typical record. A schematic shows the shape of the section. Data describe the dimensions of the section, the section properties and the structural properties such as the stiffness, failure moments, and torques. Each property is presented as a range, spanning the values which lie within the accepted specification on the dimensions and material properties. Links to Material, Process and Supplier tables can be used to find further information.

The use of the Structural Sections Data Table to select the structural section is best understood by looking at a case study. The on-line documentation system, *CES InDepth* (included with the evaluation copy of *CES*), contains a fully–worked, interactive case study on selection of structural sections.

4.3.3 A Typical Record in the Structural Sections Data Table

Name	Extruded Aluminium I-section (Y.S. 255MPa)-(55x25x0.6)			
Designation	55 x 25 x 0.6			
General				
Energy Content	235	-	335	MJ/kg
Price, C_m	2.494	-	2.756	GBP/kg
Recycle fraction	0.8	-	0.9	
Safety Factor	1.15	-	1.25	
Schematic				
Dimensions				
Maximum Depth, D	0.0546	-	0.056	m
Maximum Width, B	0.02483	-	0.02547	m
Inner Thickness, t	0.00184	-	0.00236	m
Outer Thickness, T	0.00184	-	0.00236	m
Depth between flanges, h	0.04988	-	0.05232	m
Section				
Section Area, A	1.85E-4	-	2.41E-4	m^2
Second Moment of Area (major), I_max	8.39E-8	-	1.13E-7	m^4
Second Moment of Area (minor), I_min	4.72E-9	-	6.56E-9	m^4
Section Modulus (major), Z_max	3.07E-6	-	4.04E-6	m^3
Section Modulus (minor), Z_min	3.80E-7	-	5.15E-7	m^3
Full Plas. Modulus, bend. (maj.), S_max	3.60E-6	-	4.78E-6	m^3
Full Plas. Modulus, bend. (min.), S_min	6.10E-7	-	8.37E-7	m^3
Torsion Constant, K	2.09E-10	-	4.48E-10	m^4
Section Modulus, Torsion, Q	9.09E-8	-	1.52E-7	m^3

Structural				
Mass per unit length, m/l	0.4997	-	0.6513	kg/m
Bending Stiffness (major), E.I_max	5.79E+3	-	7.80E+3	Nm^2
Bending Stiffness (minor), E.I_min	325.7	-	452.3	Nm^2
Failure Moment (major), Y. Z_max	783.3	-	1.03E+3	Nm
Failure Moment (minor), Y. Z_min	96.97	-	131.3	Nm
Full Plastic Moment (major), Y.S_max	918.8	-	1.22E+3	Nm
Full Plastic Moment (minor), Y.S_min	155.6	-	213.4	Nm
Torsional Stiffness, G.K	5.543	-	11.89	Nm^2
Failure torque, torsion, T.Q.	13.38	-	22.37	Nm
Axial Yield Load, Y.A	4.72E+4	-	6.15E+4	N
Notes				
Strength values vary with plate thickness. Al Alloy 6082T6				
Links				
Material				
Process				
Supplier				
* Indicates estimated attribute				

Chapter 5 Selector Quick Start Guide

5.1 Introduction

This *Quick Start Guide* provides a brief overview of the facilities of *Selector*. It does not offer step–by–step instructions on how to run the program, and is not comprehensive in its coverage of the facilities in *Selector*. It assumes that you are familiar with running programs under the Windows™ operating system. For detailed instructions on all aspects of the package, see the on-line Tutorials in the *Selector Help* system.

This *Quick Start Guide* has five main parts:

Section 5.2 – Getting Started	introduces the Help system and the *Project* window.
Section 5.3 – The Database	presents some features of the database; shows you the Table trees, *Attributes* and *Links* windows; and shows you how to view the attributes of a record.
Section 5.4 – On-line Books	shows you how to obtain information from the on-line book *CES InDepth*, and explains the on–line interactive case studies.
Section 5.5 – Selection	shows you how to set the Selection Table, and how to: perform a limit selection stage; plot a simple selection chart; select a subset of entities from the chart; view the selection results. It also presents various graph formatting options.
Section 5.6 – Further Facilities	shows you how to: save your work in a Project file; perform more complex selections; and export data to other applications.

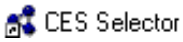
Before starting this *Quick Start* Guide, you will need to install the program by following the instructions in Chapter 2 of this manual.

5.2 Getting Started

5.2.1 Starting CES

The installation process will make a Program Manager group called 'CES Selector 3.2', which will contain the icons for *CES* software components, as shown in figure 2.7.

Double-click on the *CES Selector* icon to run the program:



You can also access the *CES Selector* Start Menu Program group from the **Programs** option on the **Start** menu (usually at the bottom left of the Windows™ screen).

5.2.2 The Welcome Screen

You will be greeted by the *Welcome* screen, shown in figure 5.1.

At the bottom of the screen is the *Selection Table* list box. This can be used to specify which of your database tables is used for selection. The contents of the list will depend on the *CES* data modules you have purchased. If you have the full *CES Engineer* package, then the list will contain: Application Areas, Materials, Process, Reference, Shape, Structural Sections, Supplier and Uses. Although it is possible to specify any of these as the *Selection Table*, the most usual choices for selections are Materials, Process and Structural Sections.

Set the Selection Table to *Materials*

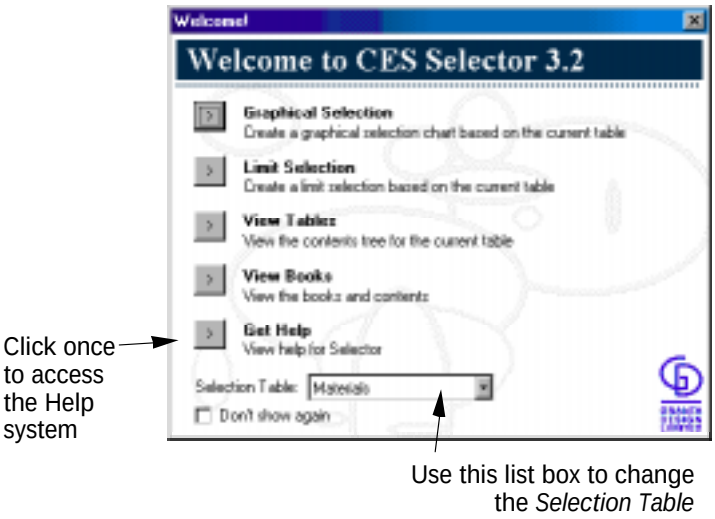

Welcome!
Welcome to CES Selector 3.2
Graphical Selection
Create a graphical selection chart based on the current table
Limit Selection
Create a limit selection based on the current table
View Tables
View the contents tree for the current table
View Books
View the books and contents
Get Help
View help for Selector
Selection Table:
Materials
Don't show again
Click once to access the Help system
Use this list box to change the Selection Table

Fig. 5.1 The *Welcome* Screen

The five buttons down the left of the *Welcome* screen lead to five frequently used options in *CES*. Click once on a button to select that option.

• The first two buttons, 'Graphical Selection' and 'Limit Selection' will start a selection stage using the *Selection Table* set in the list box. ('Materials' shown in figure 5.1)

• 'View Table' will take you to the contents of the current (Selection) table, from where you can view the attributes of some of the records.

• 'View Books' will open the on-line books – probably the default book *CES InDepth.*[3]

• The last button will take you into the on-line *Help* system.

---

[3] *CES* will attempt to open the on-line book it used *most recently* on this computer. For example, if the *Megabytes on Coppers II* CD–ROM was open when *CES* was last closed down, *CES* will attempt to open it when it is next started.

Notes:

(i) If you did a 'Compact' installation (figure 2.6), you will need to have the *CES* disk in your CD–ROM drive to view the on-line books.

(ii) To re–open the *Welcome* screen from within the program at any time, click once on the **Welcome** button on the **Standard** toolbar.

5.2.3 Help!

Obtain *Help* as follows:

Click once on the *Get Help* button on the *Welcome* screen.

The *Help Introduction* screen will appear (figure 5.2).

Every Help screen has the same set of buttons along the top (see figure 5.2). The pull–down menus along the top of the help screen are standard Windows™ *Help* functions. See your Windows™ manual for details.

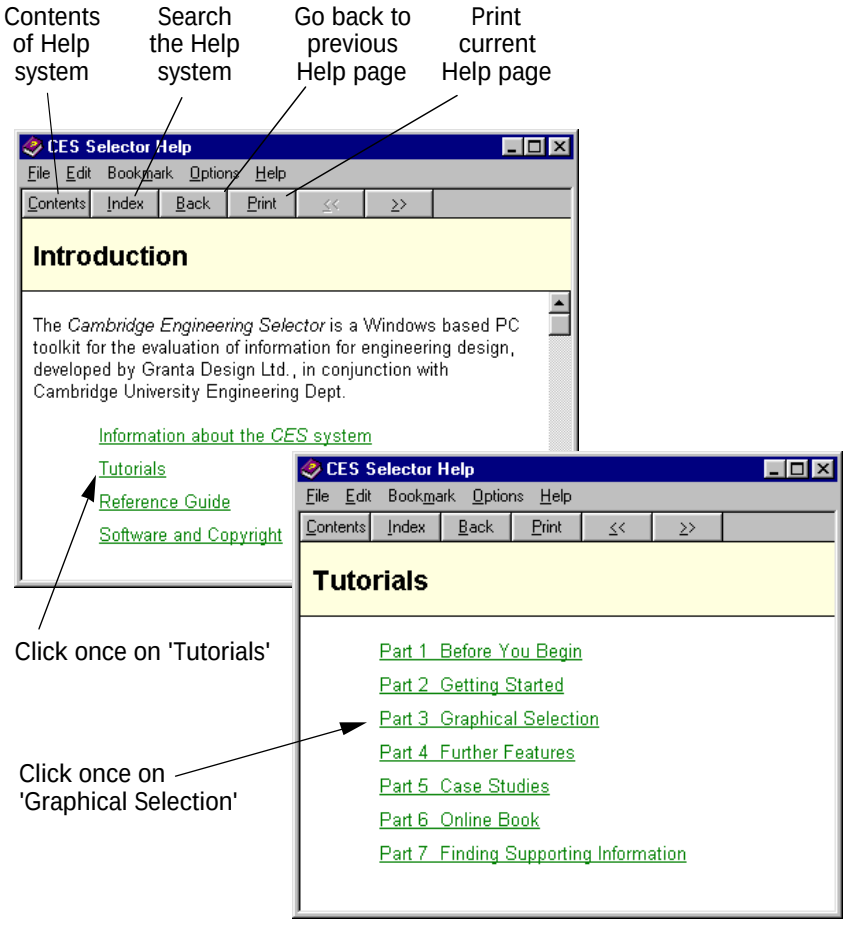

Contents of Help system
Search the Help system
Go back to previous Help page
Print current Help page
CES Selector Help
File Edit Bookmark Options Help
Contents Index Back Print << >>
Introduction
The Cambridge Engineering Selector is a Windows based PC toolkit for the evaluation of information for engineering design, developed by Granta Design Ltd., in conjunction with Cambridge University Engineering Dept.
Information about the CES system
Tutorials
Reference Guide
Software and Copyright
Click once on 'Tutorials'
CES Selector Help
File Edit Bookmark Options Help
Contents Index Back Print << >>
Tutorials
Part 1 Before You Begin
Part 2 Getting Started
Part 3 Graphical Selection
Part 4 Further Features
Part 5 Case Studies
Part 6 Online Book
Part 7 Finding Supporting Information
Click once on 'Graphical Selection'

Fig. 5.2 Part of the *Help* system.

Open one of the on-line Tutorials as follows:

In the Help window, click once on the text Tutorials

In the next help screen, click once on Part 3 Graphical Selection

Then select 3.1 Selection Charts

Then select 3.1.1 Setting the Selection Table

You will see the *Help Tutorial* screen shown in figure 5.3. Along the top of the Tutorial screen is the 'Tutorial navigation line'. This line can be used to take you forwards and backwards through the current tutorial. Simply click on the 'stations' along the line to see that part of the Tutorial. Click on the 'menu' icon at the start of the navigation line to open go back to the menu options for this Tutorial. Click on the arrows at either end of the navigation line to go to the previous and next tutorials.

Close the Help screen by clicking on the '×' at the top right of the window.

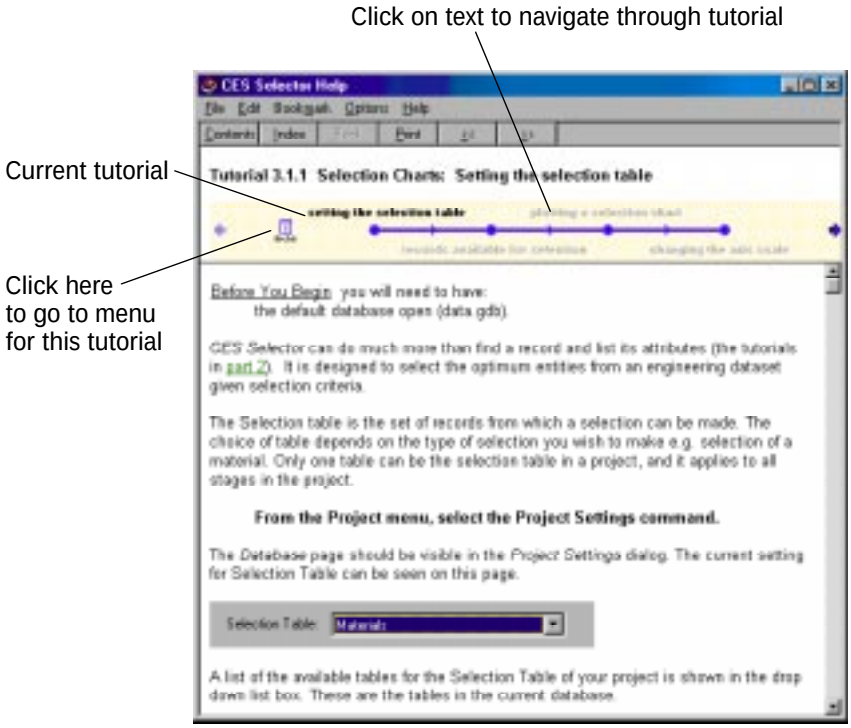

Click on text to navigate through tutorial
Current tutorial
Click here to go to menu for this tutorial
CES Selector Help
Tutorial 3.1.1 Selection Charts: Setting the selection table
Before You Begin you will need to have:
the default database open (data.gdb).
CES Selector can do much more than find a record and list its attributes (the tutorials in part 2). It is designed to select the optimum entities from an engineering dataset given selection criteria.
The Selection table is the set of records from which a selection can be made. The choice of table depends on the type of selection you wish to make e.g. selection of a material. Only one table can be the selection table in a project, and it applies to all stages in the project.
From the Project menu, select the Project Settings command.
The Database page should be visible in the Project Settings dialog. The current setting for Selection Table can be seen on this page.
Selection Table:
Materials
A list of the available tables for the Selection Table of your project is shown in the drop down list box. These are the tables in the current database.

Fig. 5.3 An on-line Tutorial

Alternative ways into the Help system are to click on the **Help** button on the standard toolbar, or select the **Help/Contents** menu at the top of the screen. Both of these options will lead you to the *Help Contents* window, shown in figure 5.4. This window can be used to search for help topics in several different ways.

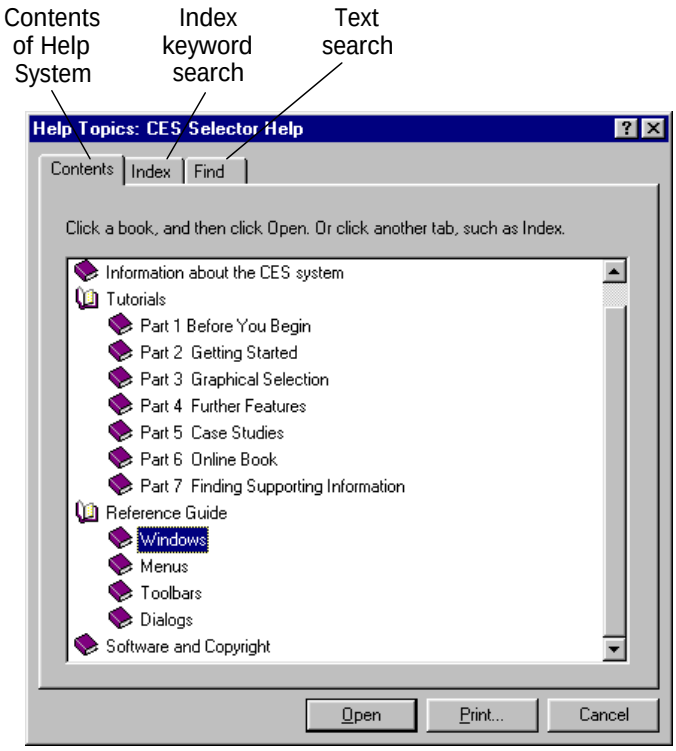


Fig. 5.4 *Help Contents* window

5.2.4 The Project Window

When you have closed the Help system, the *Project* window will be visible on the screen (figure 5.5). This window is the *central navigation point* for *CES*. The title of the current *CES* Project is displayed at the top of the window – in this case 'Heat Exchanger'. The drop-down list contains the names of all the tables in the database. Select one to view the contents of that table. The on-line books can be accessed through the tab at the far right. Information about the selection stages that have been performed in the current project is displayed in the central area of the window. Figure 5.5 shows how the *Project* window might look after three selection stages have been performed.

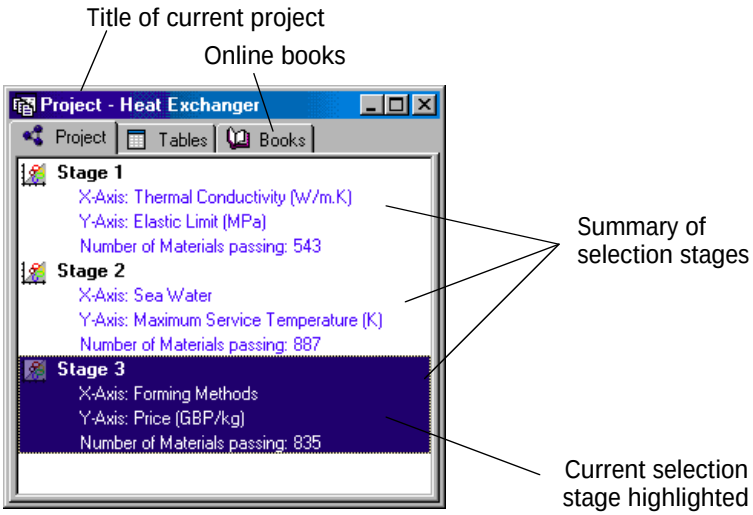


Fig. 5.5 The *Project* window, with three selection stages.

5.3 The Database

This section will show you how to list the attributes of a record in the database. As an example, we will examine the material 'Wrought Aluminium Alloy 2014–T6', and view the processes by which it can be formed. If you do not have the materials data module, follow the same procedure, but use one of the other data tables instead.

5.3.1 Table Trees and Filters

One way to find the properties of a record in the database is to use the identifier tree (Table Tree), which can be accessed from the relevant page of the *Project* window (figure 5.6).

Click on the Tables tab at the top of the *Project* window, and select the Materials Table from the drop-down list

The top level of the materials table tree will be displayed. A '+' on any branch of the tree indicates that there are more branches below it.

Open the 'Metals' branch by clicking once on the '+' to the left of 'Metals'

Open 'Light Alloys', then 'Aluminium'

'Wrought Aluminium Alloys' (MMLAALW–) is a *generic* record, whose attributes span the range of attributes of a number of *specific* records below it in the tree (in this case, all wrought aluminium alloys) This fact is indicated by the generic record icon on its branch of the tree (see section 3.2.4). View the *specific* wrought aluminium alloys as follows (see figure 5.6):

Click on the new '+' next to 'Wrought' with the *left* mouse button to open the Wrought branch.

Finally open the 2000 series branch and the 2014 branch.

The Table tree should now look something like figure 5.6.

Double-click with the left mouse button on the material 2014–T6 to view its attributes.

(To see the contents of the generic record 'wrought aluminium alloys', double click with the left mouse button on 'Wrought')

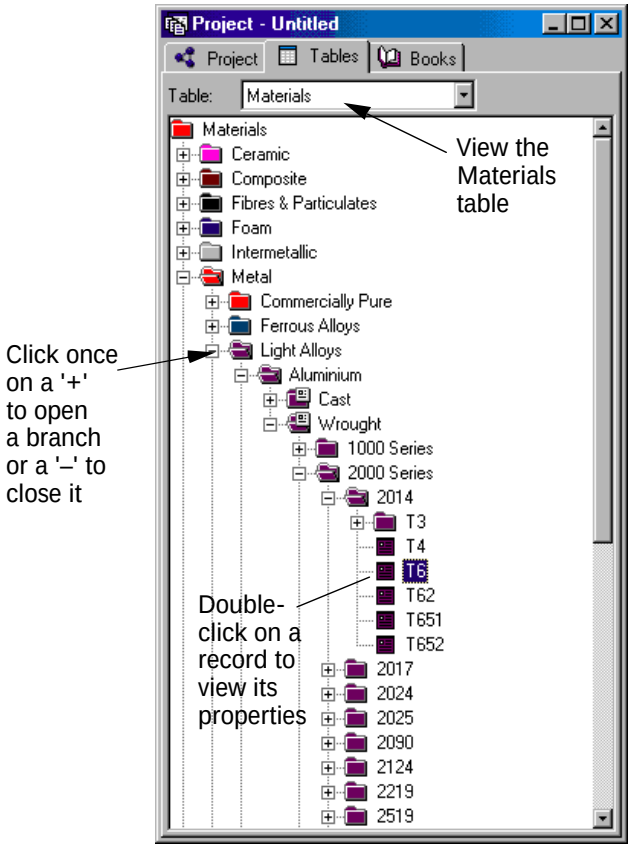


Fig. 5.6 Opening the materials table tree.

The default *filter* for materials selection is called 'All Bulk Materials' (See section 3.2.6). This filter displays about 2910 materials - from each of the main classes. It does not display about 700 material records in the database which are not normally used in bulk form in engineering applications. Examples of these are fibres and particulates which are used in composites, but not normally on their own. However, these records can be accessed readily whenever they are needed using the <All Records> filter on the **filters** toolbar (below), which lists all 3660 or so materials in the database.

5.3.2 The Attributes Window

The *Attributes* window will now display information about 2014–T6, as shown in figure 5.7. There are several 'pages' of information in the listing, and you can use the scroll bars to view these.

Each attribute can take a range of values, for example the elastic limit (yield strength) of this material lies in the range 420 to 430 MPa. Some properties, for which data is not available, are estimated, and indicated by a '*' – see section 3.6. (Note that the material properties in the database are defined in the on-line book *CES InDepth*.)

The contents of the *Attributes* window can be printed using the **Print** command on the **File** menu at the top left of the screen (**File/Print**). Alternatively, the contents can be copied using **Edit/Copy,** and then pasted into another Windows program, eg a word-processor or spread sheet.

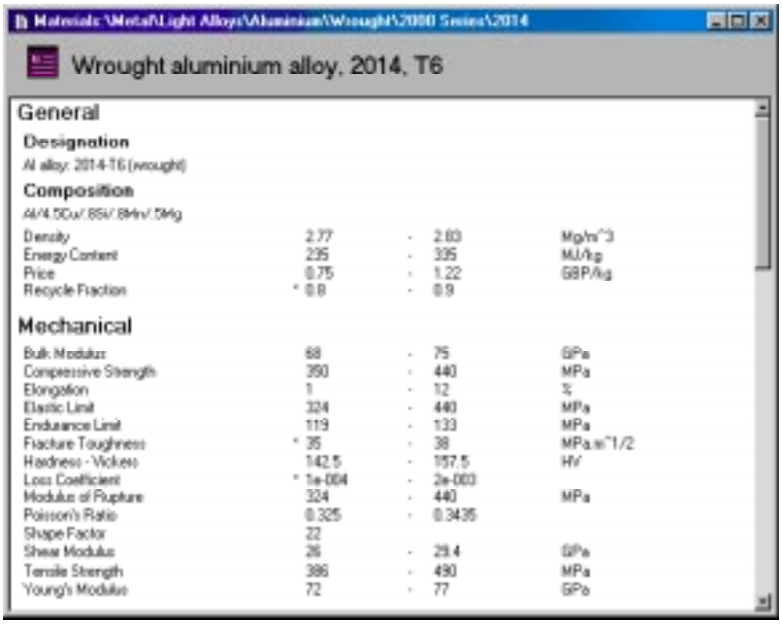

Wrought aluminium alloy, 2014, T6
General
Designation
Al alloy: 2014-T6 (wrought)
Composition
Al/4.5Cu/.85Si/.8Mn/.5Mg
Density 2.77 - 2.83 Mg/m^3
Energy Content 235 - 335 MJ/kg
Price 0.75 - 1.22 GBP/kg
Recycle Fraction * 0.8 - 0.9
Mechanical
Bulk Modulus 68 - 75 GPa
Compressive Strength 350 - 440 MPa
Elongation 1 - 12 %
Elastic Limit 324 - 440 MPa
Endurance Limit 119 - 133 MPa
Fracture Toughness * 35 - 38 MPa.m^1/2
Hardness - Vickers 142.5 - 167.5 HV
Loss Coefficient * 1e-004 - 2e-003
Modulus of Rupture 324 - 440 MPa
Poisson's Ratio 0.325 - 0.3435
Shape Factor 22
Shear Modulus 26 - 29.4 GPa
Tensile Strength 386 - 490 MPa
Young's Modulus 72 - 77 GPa

Fig. 5.7 The *Attributes* window, showing the first page of properties of wrought aluminium 2014–T6.

5.3.3 Forms

A Form is a template that specifies the attributes that are visible and their layout, in the *Attributes Window*[4]. In figure 5.7, the form used is the default form called 'Generic', which displays attributes that are applicable to all classes of materials. Other forms display the properties that are relevant to particular classes of materials (e.g. polymers), or some other subset of properties. The 'Composition' form shows only information

[4] The current form also sets the attributes that are available during Selection stages.

about the composition of the material. For many materials, this means the proportions of various elements in their chemistry.

Set the current form to 'Composition' (figure 5.8)

The properties listed in the *Attributes* window are now the percentage by mass of the various elements that make-up 2014-T6 (figure 5.8).

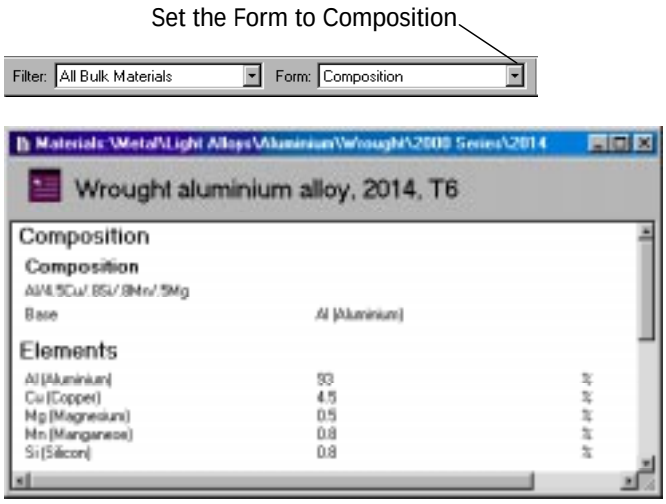


Fig. 5.8 The *Attributes* window, showing the properties of wrought aluminium 2014–T6 with the 'Composition' Form set.

It is often (but not always) desirable to set the Form and Filter to have the same name. For example if you wish to view detailed data for metals, set both the Filter and Form to 'Metal'. The Filter will then limit the materials available (for viewing and selection) to metals, and the *Attributes* window will show just the properties relevant to metals, as specified in the Metal Form.

Set the Filter and the Form to 'Metal'

View the first page of attributes for Aluminium 2014-T6 again.

Notice that there are two new properties visible in the *Attributes* window, compared to those available in the 'Generic' form (figure 5.7). They are the 'UNS Number' (Al9201) and the 'Fatigue Strength Model', in the Mechanical Properties. Note that the Fatigue Strength Model attribute has two buttons next to it: and . The presence of these two buttons indicates that 'Fatigue Strength Model' is a 'functional' property (see section 3.3.1). (Further down the *Attributes* window, are other properties that are only relevant for metals, and hence are not available on the 'Generic' form.)

5.3.4 Viewing Functional Data

All metals in the materials table have a fatigue strength model or 'S-N' curve (applied stress vs no of cycles to failure). The fatigue strength depends on two parameters: the stress ratio, '*R*' (ratio of minimum applied stress to maximum applied stress), and the

number of cycles to failure '*N*'[5]. These parameters have default values of R=-1 and $N = 10^7$, respectively.

Click on **to see the parameters used to evaluate the Fatigue Strength Model**

Click on **to see a graph of the function.**

The *Functional Graph Properties* dialog will appear (left of figure 5.9). This dialog box enables you to set various options for the display of the function: (i) Select the 'No of Cycles' parameter (*N)* to be plotted on the X-axis and (ii) accept the 'Project Default' parameters (in this case R=–1) at the bottom of the dialog box, or change the parameter values.

Note that if the 'Project Defaults' check box at the bottom of the dialog is ticked, the graph will be plotted using the *project default* parameters. If it is not ticked, then the graph will be plotted using whatever parameter values you enter when you click on *Edit*. (See Section 3.3.9 for further details about *default parameters*.)

Click on OK to plot the graph.

The graph on the right of figure 5.9 will appear. It shows the fatigue strength calculated by the model as a function of *N*, with *R* set to -1.

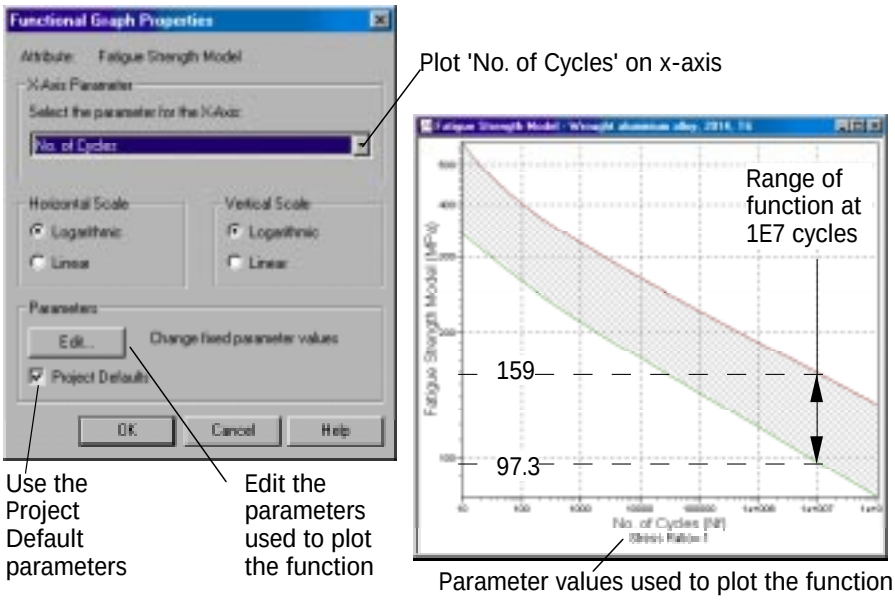


Fig. 5.9 Fatigue Strength Model for 2014-T6: An example of functional data.

At a value of $N = 10^7$ (1E7) cycles (the Project Default), the function ranges between values of 97.3 MPa and 159 MPa. These are the values displayed for the fatigue strength on the Attributes form.

---

[5] The fatigue model is based on the Basquin and Coffin-Manson approximations for high and low cycle fatigue. It uses Goodman's rule to model the dependence on stress ratio. See Section 2.2.2 of *CES InDepth*.

Try plotting the fatigue strength as a function of stress ratio *R*, by changing the X-axis parameter in the *Functional Graph Properties* dialog

It is possible to edit the parameters used to plot the graph, using the *Edit* button at the bottom of the dialog. If the check box is ticked when you click on *Edit* you will edit the Project Default parameters. If the check box is not ticked, you will just edit the parameters used to plot the graph, but the project defaults will not be changed.

Set the Filter back to 'All Bulk Materials' and the Form to 'Generic' when you have finished.

5.3.5 Viewing Links

At the bottom of every page of attributes, is a set of *Links* buttons. These buttons are used to view records in other tables that are linked to this record. These might be *processes* that can be used to form this material, or companies who *supply* it, or the *shapes* to which it can be formed, etc.

Scroll down to the bottom of the *Attributes* window (figure 5.10)

Click once on the Process Link button

The links window will appear (figure 5.11), showing all the processes that can be used to shape 2014–T6. (These links can be used in for selection purposes, as explained later.)

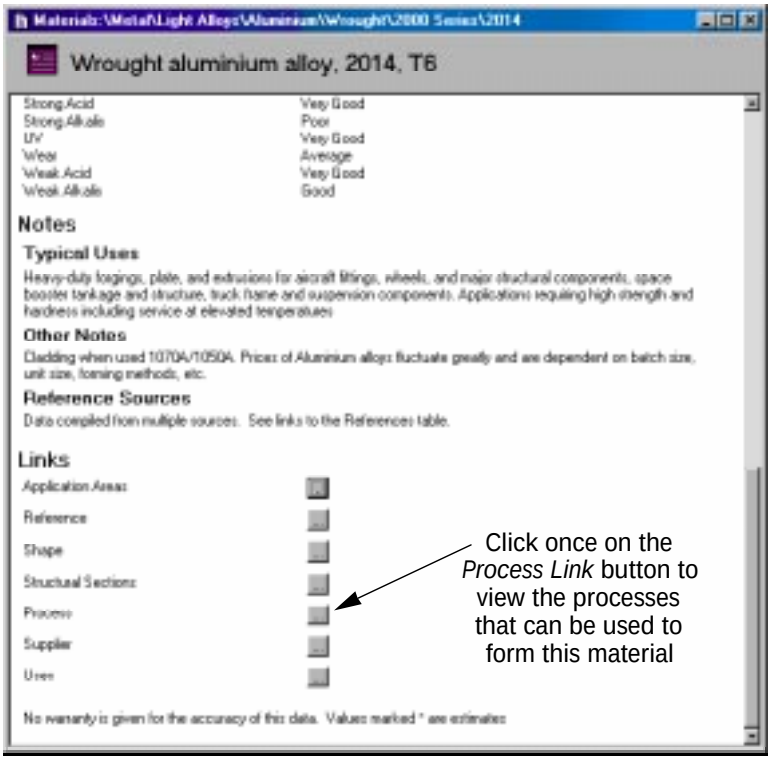

Wrought aluminium alloy, 2014, T6
Strong Acid Very Good
Strong Alkali Poor
UV Very Good
Wear Average
Weak Acid Very Good
Weak Alkali Good
Notes
Typical Uses
Heavy-duty forgings, plate, and extrusions for aircraft fittings, wheels, and major structural components, space booster tankage and structure, truck frame and suspension components. Applications requiring high strength and hardness including service at elevated temperatures
Other Notes
Cladding when used 1070A/1050A. Prices of Aluminium alloys fluctuate greatly and are dependent on batch size, unit size, forming methods, etc.
Reference Sources
Data compiled from multiple sources. See links to the References table.
Links
Application Areas
Reference
Shape
Structural Sections
Process
Supplier
Uses
No warranty is given for the accuracy of this data. Values marked * are estimates
Click once on the Process Link button to view the processes that can be used to form this material

Fig. 5.10 *Attributes* window showing the **Links** buttons.

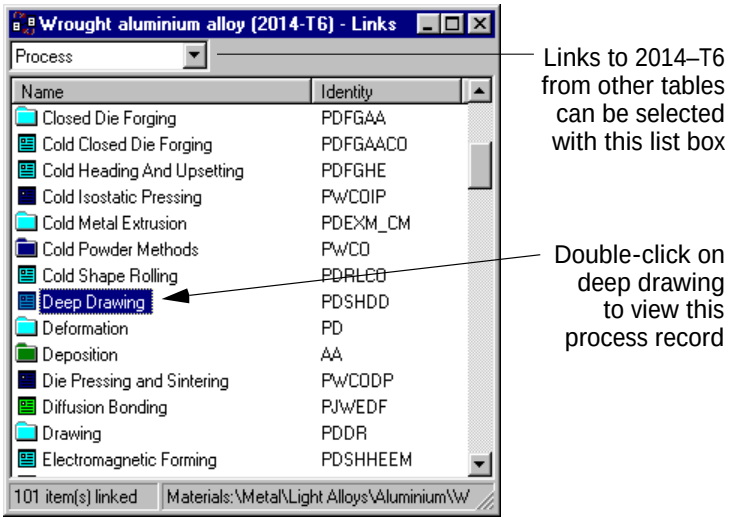


Fig. 5.11 Process Links for aluminium 2014–T6.

To view links to 2014–T6 *from other tables*, eg Suppliers, or References, select the table name of interest from the list box at the top left of the *Links* window. Alternatively, return to the *Attributes* window and select one of the other links buttons.

To view the attributes of an item in the *Links* window, simply double-click on it...

Double–click on 'Deep Drawing'

Details of the process will appear in a new *Attributes* window (figure 5.12). Scroll down the record to see more information about the process. At the bottom you will find **Links** buttons, including one for materials. Clicking on this button will generate a list of all the materials that can be formed by deep drawing. Among them, of course, will be 2014–T6.

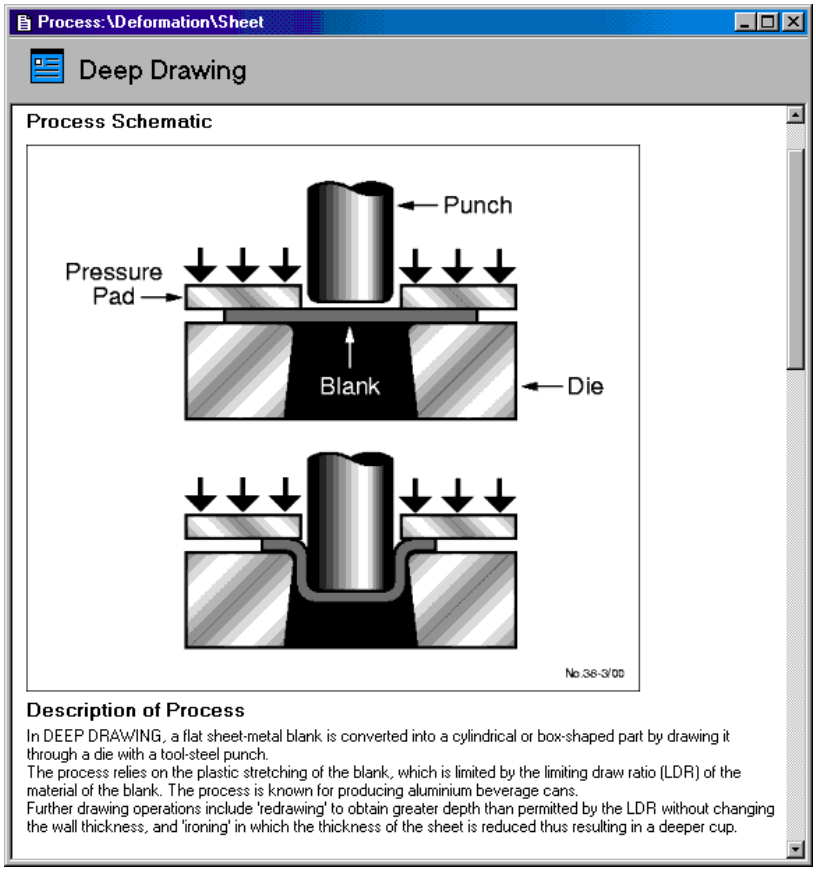

Process:\Deformation\Sheet
Deep Drawing
Process Schematic
Punch
Pressure Pad
Blank
Die
No.38-3/00
Description of Process
In DEEP DRAWING, a flat sheet-metal blank is converted into a cylindrical or box-shaped part by drawing it through a die with a tool-steel punch.
The process relies on the plastic stretching of the blank, which is limited by the limiting draw ratio (LDR) of the material of the blank. The process is known for producing aluminium beverage cans.
Further drawing operations include 'redrawing' to obtain greater depth than permitted by the LDR without changing the wall thickness, and 'ironing' in which the thickness of the sheet is reduced thus resulting in a deeper cup.

Fig. 5.12 *Attributes* window, showing the first screen of information for the process 'Deep Drawing'.

5.4 The On–line Books

CES contains an on–line documentation system, which provides a wide variety of information to support users. The default book, called *CES InDepth*, includes background on the selection process; information about the *CES* databases; solutions to many standard engineering problems; 50 interactive case studies on material, process and shape selection; and more (figure 5.13).

A number of other CD–ROMs can be purchased from Granta Design and run within *CES*. They are linked directly to entities in the *CES* databases (generally materials and manufacturing processes) and can be used as sources of 'supporting information' during the selection process[6]. The current on–line book can be changed using the **Books/Change Book...** menu.

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[6] At the time of writing, these CD–ROMs include: 'Megabytes on Coppers II', The Butterworth–Heinemann 'Engineering Materials Selector', and 'Steelspec'. Contact Granta Design for details.

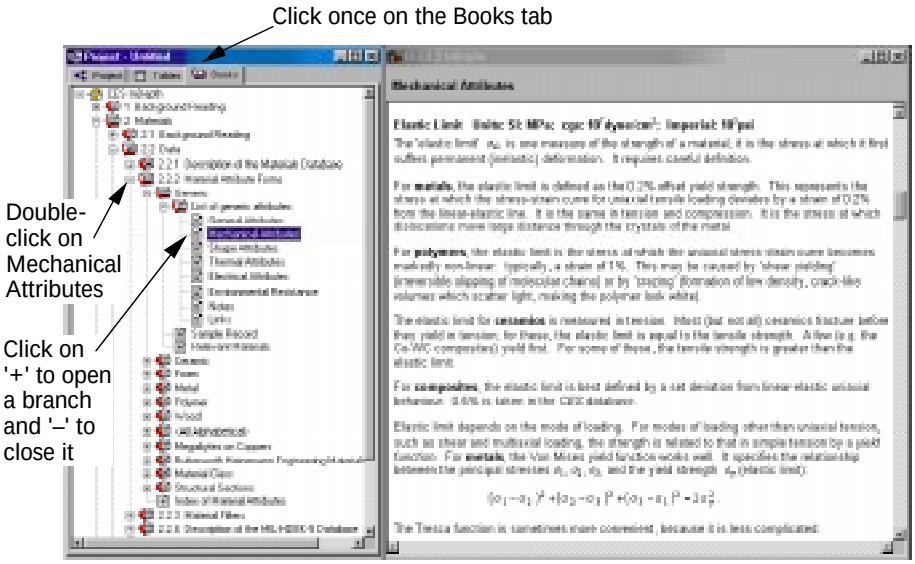

Fig. 5.13 The *Project* Window, showing the contents of *CES InDepth*, and a page of information with the definition of the material attribute 'Elastic Limit'

5.4.1 CES InDepth

Click once on the Books tab at the top right of the Project window

Click once on the '+' next to *CES InDepth*, then click on the '+' next to '2 Materials' to open the Materials chapter

Open the branches of the contents tree down to 'List of generic attributes' as shown in figure 5.13

Double-click on 'Mechanical Attributes', then select 'Elastic Limit'

The *Books* window will now show the definition of the material attribute 'Elastic Limit' that is used in *CES* (figure 5.13).

CES InDepth contains a large amount of useful information about the system. It is worth taking a little time to explore the contents. You will find the *Books* toolbar useful for this. See Appendix A, figure A4 for details. (The same options are available on the **Books** pull–down menu at the top of the screen.)

5.4.2 Searching the Books

The on-line books can be searched in a variety of ways. The simplest is a text search, which can be performed as follows:

Click once on the Books Search button **or use the *Books/Search* menu**

In the resulting dialog box (figure 5.14), select the 'Query' tab

Then type the search string: process near "case study"

Finally click on the *Find* button to perform the search.

This will search through the books for any instances of the string 'process' *near* the string "case study". (The definition of 'near' can be set on the **Tools/Options/General** menu. The default distance is 8 words).

The search results will appear in the *Search Results* window, figure 5.15. There are fourteen instances in *CES InDepth* which satisfy the search criteria. We will examine the case study on process selection for a Spark Plug Insulator.

Double–click on '3.3.10 Spark Plug Insulator' (figure 5.15)

The *Books* window will reappear, showing information about the case study (figure 5.16). Scroll down to see more.

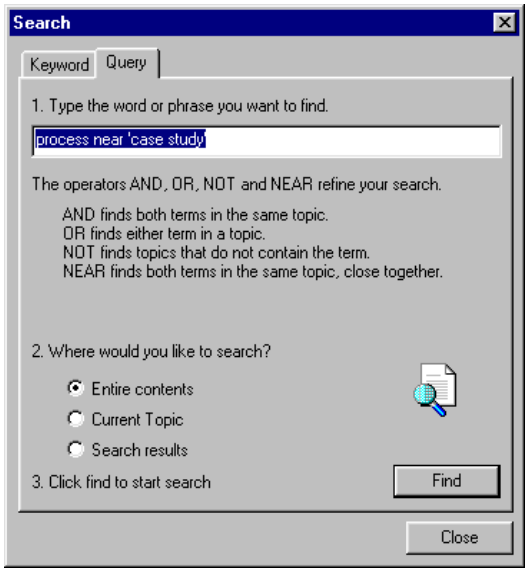
Search
Keyword
Query
1. Type the word or phrase you want to find.
process near 'case study
The operators AND, OR, NOT and NEAR refine your search.
AND finds both terms in the same topic.
OR finds either term in a topic.
NOT finds topics that do not contain the term.
NEAR finds both terms in the same topic, close together.
2. Where would you like to search?
Entire contents
Current Topic
Search results
3. Click find to start search
Find
Close

Fig. 5.14 *Books Search* dialog box.

5.4.3 On–line Case Studies

The on–line case studies can also be found simply by opening the *Books* contents page to the relevant sections, (as per figure 5.13). Materials selection case studies are in section 2.3 of *CES InDepth*, Process selection case studies are in section 3.3, and structural sections selection case studies are in section 5.4.3.

Each case study has a description of the problem and a list of design requirements, (see figure 5.16), followed by a worked solution containing all of the relevant *CES* output.

It is also possible to get *CES* to *run the case study automatically*, by clicking on the 'interactive case study' button, shown in figure 5.16. This button (or a link to it) can be found near the start of each case study. Using it gives you the opportunity to edit the selection stages in the worked example, add more of your own and explore the selection results in detail. We suggest that you read the worked example before running the interactive version of the case study.

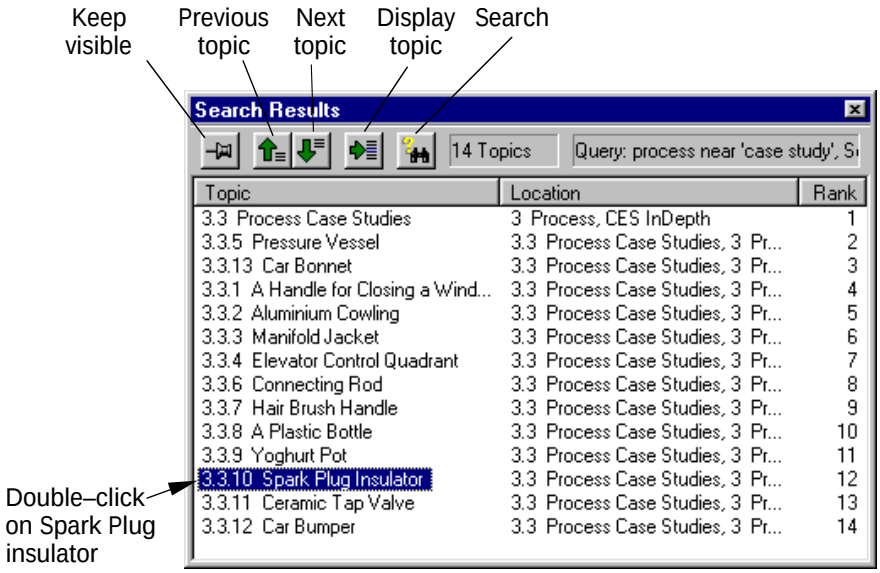

Fig. 5.15 Search results: pages in *CES InDepth* containing the string 'process' near the string 'case study'.

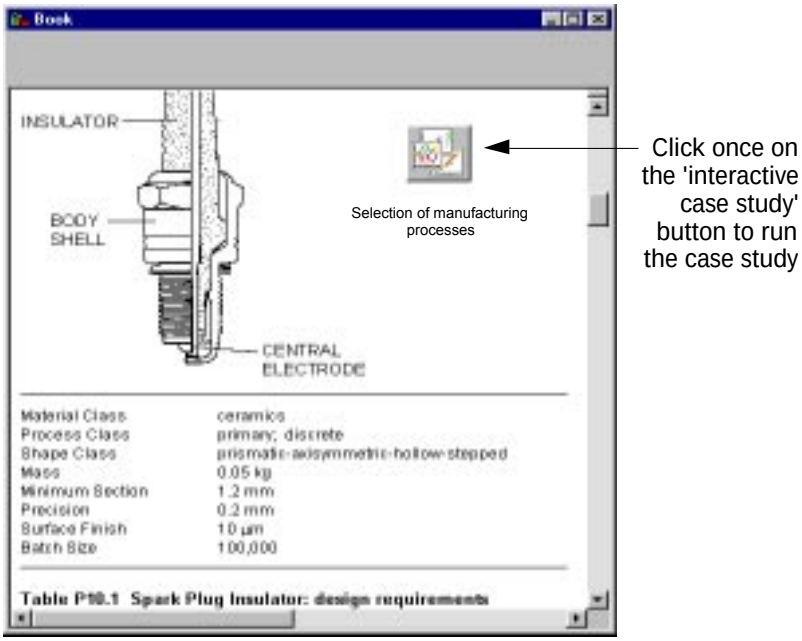

Fig. 5.16 Part of the Spark Plug Insulation case study, in *CES InDepth*.

5.5 Selection

This section shows you how to perform a simple 'limit' selection, how to plot selection charts, how to select a subset of entities from the chart, how to view the selection results and some graph formatting options.

5.5.1 Changing the Selection Table

The first example in this section will be selection of a manufacturing process for a spark plug insulator. (You will only be able to do this if you purchased a database containing the Process Table (eg *CES Engineer*). It will probably be necessary to change the *Selection Table* before you do this (depending on the setting you chose on the *Welcome* screen, figure 5.1).

Select the *Project/Project Settings* option from the drop down menu at the top of the screen

Set the Selection Table to 'Process' in the top list box

Click once on OK

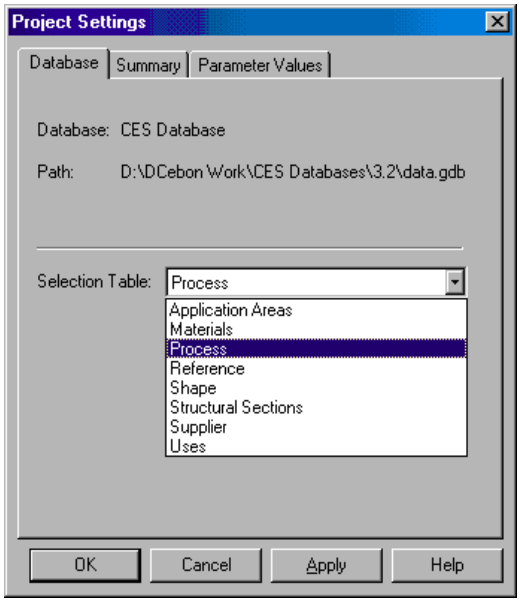

Fig. 5.17 *Project Settings* dialog

5.5.2 Performing Limit Selections

The design requirements for the spark plug insulator can be seen in figure 5.16. It must be made from a ceramic (Alumina, Al_2O_3), using a discrete, primary process (one which can make individual components from a raw material). The mass of the component will be approximately 50 grams, its minimum section will be 1.2 mm, the surface finish must have an RMS roughness less than 10 µm, the batch size will be at least 100,000, and so

on. Most of these requirements can simply be entered as upper and/or lower limits in the *Limit Selection* form.

Click on the Limit Selection button **on the *Project* toolbar**

Enter the design requirements as shown in figure 5.18.....

Attribute	*Minimum*	*Maximum*	*Units*
Mass range (normal)	**0.04**	**0.06**	**kg**
Roughness (normal)		**10**	**µm**
Section (normal)	**1.2**		**mm**
Tolerance (normal)		**0.2**	**mm**
Economic batch size (units)	**100000**		
Primary	√		
Discrete	√		

Click once on the Apply button at the top of the window to perform the selection.

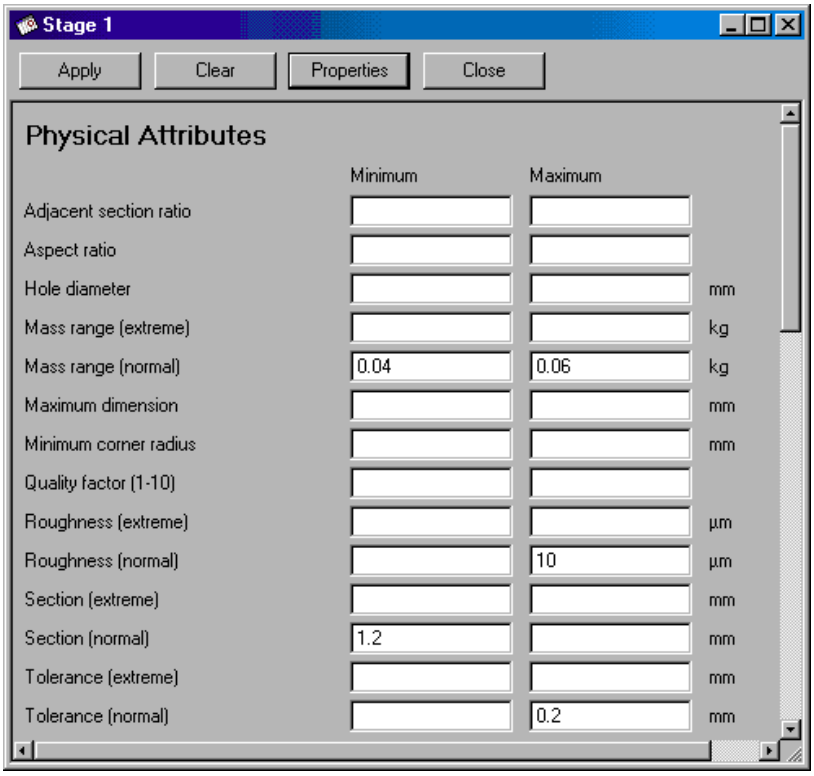

Fig. 5.18 Selecting processes for a spark plug insulator, using the *Limit Selection* window.

5.5.3 Selection Results

To view the results of your selection, open the *Selection Results* window as follows:

Select the *View/Results* option from the drop–down *View* menu.
(Alternatively, click on the Results button on the *Standard* toolbar.)

The default format for the *Selection Results* window is entities passing 'All stages', as shown in figure 5.19. Since one selection stage has been performed, the processes currently shown in the list are the ones that passed the *Limit* stage. If you had performed more than one selection stage, the list would show only the processes that had passed them all. The *Selection Results* window can be set to various other formats by changing the drop–down list box at the top left corner of the window. You could examine the attributes of one of the processes on the list by double-clicking on it. This would open the *Attributes* window with the properties of your selected process.

The results window in figure 5.19 shows nine possible processes. In fact, only two are suitable for manufacturing the spark plug insulator. They are 'Die Pressing and Sintering' and 'Powder Injection Moulding'. The reason is that these are the only ones that can process *ceramics*. We could easily reach this conclusion by performing another stage to select only those processes that can form ceramics. This requires the use of a slightly more advanced facility in *CES* 'table-tree selections', which will be discussed later in this chapter.

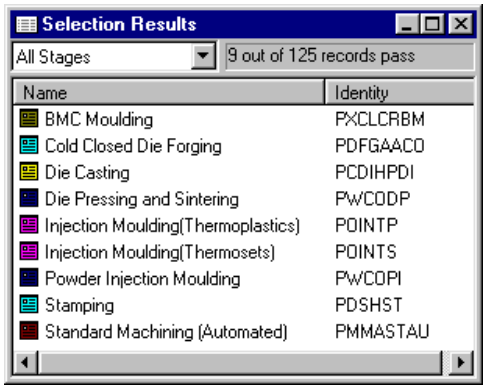

Fig. 5.19 Results of the process selection *Limit* stage.

5.5.4 Plotting a Selection Chart

The next example will investigate selection of materials. So it will be necessary to change the Selection Table. (Follow the instructions in section 5.5.1)

Change the *Selection Table* to 'Materials'
(Click on 'Yes' in the warning message dialog box)

Suppose you wish to find materials with relatively low densities and high strengths. The best way to use *CES* for this is to plot a selection chart of *elastic limit* against *density*, and then select all materials in the area of interest.

Note: The *Elastic Limit* is one measure of the strength of a material; it is the stress at which it first suffers permanent (inelastic) deformation. For metals the elastic limit is the yield strength, for polymers it is the stress at which the uniaxial stress strain curve becomes markedly non-linear, typically at 1% strain. There are other definitions for

other classes of materials. See *CES InDepth* for definitions of material attributes. (See also figure 5.13).

Plot a selection chart as follows:

Click once on the *New Graphical Stage* button on the Standard toolbar. (Alternatively select the menu option *Project/New Graphical Stage*)

The *Graph Stage Wizard* dialog box will appear (figure 5.20). Select 'density' for the x-axis of the chart, then select 'elastic limit' for the y-axis of the chart:

Click once on the *X-Axis* tab (top left of the dialog box).

Select 'Density' from the Attributes list box as shown

Repeat the process to select 'Elastic Limit' for the Y-Axis.

Finally click once on *OK* to exit the *Graph Stage Wizard*.

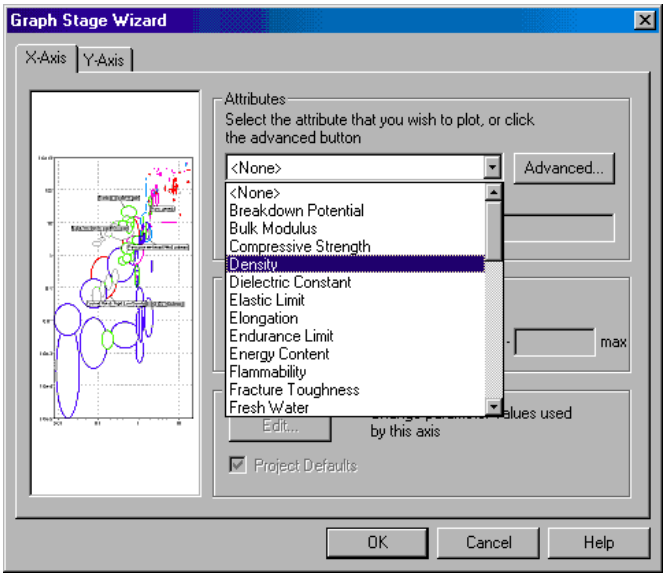

Fig. 5.20 Choosing properties for the X-axis of a selection chart.

A selection chart will appear on the screen (figure 5.21). The colours of the material bubbles indicate their main classes as indicated on the Materials table tree in the *Project* window. Note that the axes are logarithmic by default, since the properties span such a wide range of values. This can be changed by selecting linear scales in the *Graph Stage Wizard* dialog box, or using the **Stage Properties** button on the *Project* toolbar.

Click *once* on any material 'bubble' on the chart to see a label showing its identity. You can change the format of the label using a right mouse click.

5.5.5 Selecting Materials within a Property Range

Now select all materials in the database with density and elastic limit in the range: 1 Mg/m^3 < density < 10 Mg/m^3, and 100 MPa < elastic limit < 3000 MPa.

Click once on the *Box Selection* button on the *Project* toolbar

Click once on point (x, y) = (1.0, 100) on the chart, and hold the mouse button down (The coordinates of the cursor are shown at the bottom left of the screen.)

Drag the cursor to a point near (10.0, 3000) on the chart, then release the mouse button. (3000 = 3.0E3).

Materials within the box, and all materials that *cross* the boundary of the box are now plotted in colour. This indicates that they have been included in the current subset of materials – they 'passed' the selection stage. Materials that are not included in the subset have been plotted in grey because they 'failed' the selection stage.

Optionally, click the *Hide Failed Records* button to hide the grey bubbles

You can change your selection at any time by re–sizing the selection box. Click once on the side of the box to reveal square 'handles'. Click on a handle and, while holding the mouse button down, move it to a new position.

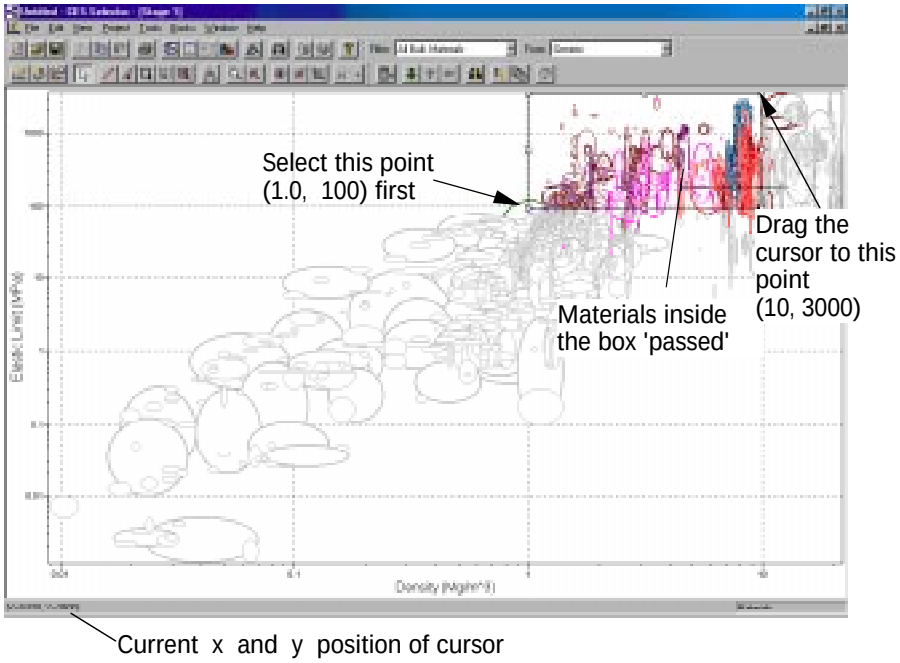

Fig. 5.21 Materials selection chart of Elastic Limit vs. Density. Selecting materials within a 'box'

5.5.6 Maximising a Performance Index

In many cases it is desirable to select materials so as to maximise a combination of material properties, a 'performance index'. One such combination is the 'specific strength' or strength/weight ratio:

$$M = \sigma_{el}/\rho,$$

where σ_{el} is the elastic limit and ρ is the density.

Taking logarithms of both sides of this equation, gives

$$\log_{10} \sigma_{el} = \log_{10} \rho + \log_{10} M.$$

This equation can be plotted on a selection chart with logarithmic axes, as a line of slope 1.0 with an intercept of $\log_{10} M$ (at $\rho = 1.0$). All materials that lie along such a line have the same value of M. Materials above the line have a higher value of M and will perform better if high strength and low weight is needed. A list of performance indices for standard design cases can be found in *CES InDepth*.

To select a subset of materials with a high value of M, do the following:

Click once on (gradient–line selection button) on the *Project* toolbar

The program will now present you with the dialog box *Line Selection*. The default slope is 1.0, which is what you want for M, so:

Click once on OK to accept the slope of 1, then

Click once on a point near (1.0, 200) on the chart. Hold down the mouse button and drag the line to (1.0, 200) and release it. (See the coordinates at the bottom left of the window.)

A diagonal selection line will appear on the chart (figure 5.22)

Click once on a point above the line with the hand cursor, to indicate that you want to select materials in that area (those with high σ_{el}/ρ)

All materials above the line and all materials that cross the line 'passed' the selection stage and will now be plotted in colour. All other materials 'failed' and they will be plotted in grey. You can move the selection line to change your selection: move the cursor over the line until it changes to 'four–way arrows', then 'drag and drop' the line to a new position.

Note that this line selection superseded the previous 'box' selection because only one selection is possible on each stage.

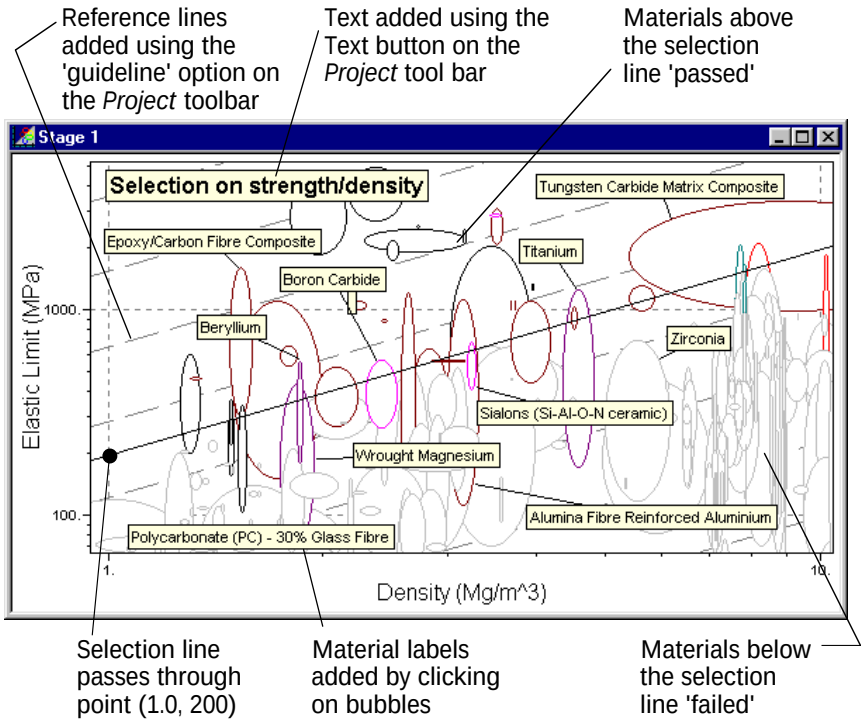

Fig. 5.22 Selecting a subset of materials with $\sigma_{el}/\rho > 200$ MPa.m^3/Mg
Other formatting information added using buttons on the *Project* toolbar.

5.5.7 Graph Format Options

Next zoom–in on part of the chart, and add some extra formatting information, so as to make it look like figure 5.22:

Click once on the *Magnify* button **on the *Project* toolbar**

Click once on point (1.0, 10) on the chart, hold the mouse button down, then drag the cursor to a point near (10.0, 5000) on the chart.

Now add some material name labels:

Click once on a material bubble, to generate a label.

Change the format of the label by clicking with the right mouse on the label and selecting the *Format Label* option from the context menu. (You can change the text in the label by selecting other options from the context menu.)

Select the type size and text format, then click on *OK* to exit.

The label that appears on the selection chart can be moved by 'dragging and dropping' it with the mouse.

Repeat these steps to label other materials. (Note that you can set the *default* format for labels from the ***Tools/Options/Labels*** menu.)

You can also add text to the chart using the **Text** button on the **Project** toolbar, and you can draw a set of parallel lines of any desired slope across the chart using the **Guidelines** button. Your chart should end up looking something like figure 5.22.

The selection chart can be printed using **File/Print**. You can also use the **Edit/Copy** to send a copy of the chart to your Windows™ clipboard. The contents of the clipboard can then be pasted into another Windows™ program (eg, word processor).

5.6 Further Facilities

This section shows you how to change units and currencies, save your work in a Project file, how to select materials using more complex selection charts, and how to export files containing property lists or selection results.

5.6.1 Units and Currency

The default units and currency used by *CES* are obtained automatically from your computer's Regional Settings which are defined by Windows™. (See the *Regional Settings* Control Panel in Windows™.) These regional settings are denoted <Automatic> in the *Tools/Options* dialog shown in figure 5.23.

Open the *Tools / Options* dialog

To change the currency (eg to US$), or the units (eg to 'US Imperial'), simply select different settings in the list boxes. All attribute data –in property lists or selection charts, etc, will change automatically.

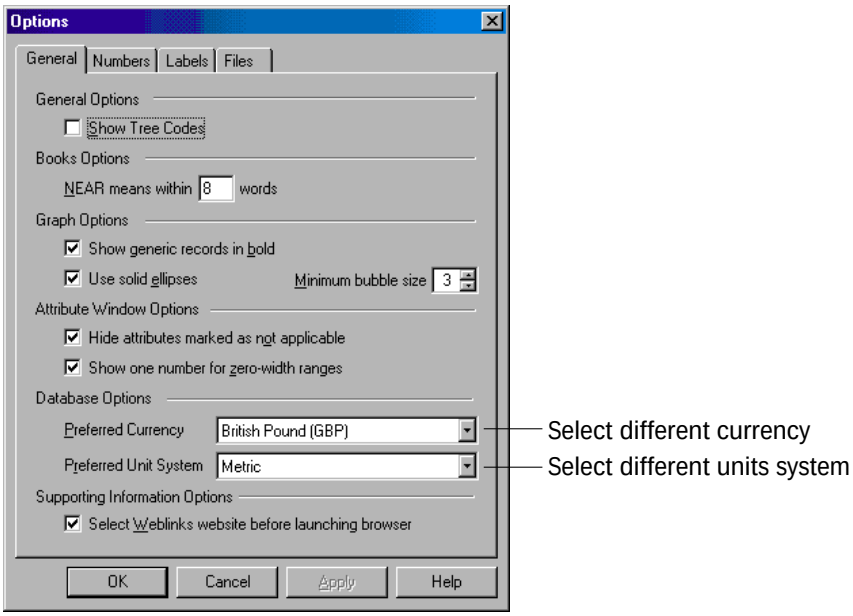

Fig. 5.23 *Options* dialog

5.6.2 Project Files

To save your work in a project file, do the following:

Open the Project/Settings dialog (figure 5.17). Then select the *Summary* tab.

Enter the title of the project, the author and a description, then exit the dialog.

Select *File/Save Project As.* The *Save As* dialog box will open.

Set the File Type in the drop–down list box (bottom of the dialog box) to 'Selector Project (*.ces)'

Enter the file name 'sample.ces' in the input field

Set the file directory using the directory tree options at the top of the window

Click once on *Save* to save the file and exit the dialog box.

Your current *CES* session can be saved again at any time by selecting **File/Save Project** (Ctrl+S). If you wish to open an old project file, use **File/Open Project** – but beware, this will overwrite the current state of the program – so you will lose any selections currently on the screen. If you think you might need them again, save your selections before opening another project file.

5.6.3 Some Other Chart Options

The following illustrates the second type of materials selection chart: a bar chart. We will plot a graph of a 'user–defined' numerical property as a function of the type of material – ie its position on the material table tree. This is sometimes called a 'table tree selection'.

Start by clearing all previous selections, and then set–up the X-axis to contain the five main material Identifiers.

Select *File/New Project*

Start a new graphical selection stage

Select the X-Axis tab and then the *Advanced* button in the *Graph Stage* Wizard. This will display the *Set Axis* dialog, shown in figure 5.24.

Click once on 'Trees' tab at the top of the lower window pane, and select the 'Materials' table from the drop-down list. This will display a copy of the materials table tree in the lower window pane.

Click once on each of the material folders in the lower pane, then click on *Insert* to send it to the expression field: Ceramic, Composite, Foam, Metal, etc.

Click on OK to exit the dialog box.

Note that it is also possible to perform 'cross-tabular' selections – based on the links between tables – using the same procedure. For example, you could select all materials that can be formed by (are linked to) a particular process, by selecting the Process table from the drop-down list (figure 5.24). The Process table tree will then appear in the lower window pane. Simply select the processes or process classes of interest from the tree (eg injection moulding).

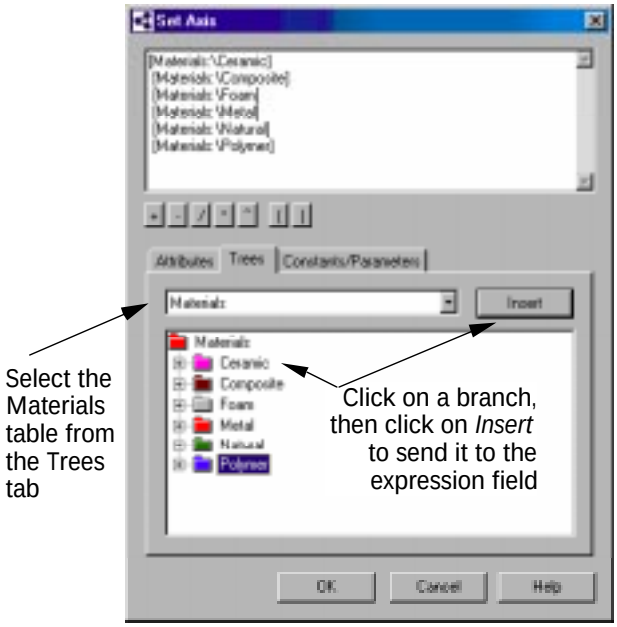

Fig. 5.24 *Set Axis* dialog, showing the selection of material classes for a graph axis.

Now generate a 'user defined' property representing the performance index $M = \sigma_{el}/\rho$ for the Y–axis of the chart as follows:

Select the Y-Axis tab and then the *Advanced* button in the *Graph Stage* Wizard.

Select the 'Attributes' tab (figure 5.25)

Double–click on 'Elastic Limit' in the lower pane to send it to the expression

Click once on the divide button / in the middle of the window (or type "/")

Then double-click on 'Density' to generate the expression shown in figure 5.25.

Click on OK to exit the *Set Axis* Dialog

Enter the name of the new property: 'Strength/Density MPa/(Mg/m^3)' in the Title field in the *Graph Stage* Wizard

Click on OK to exit the Wizard.

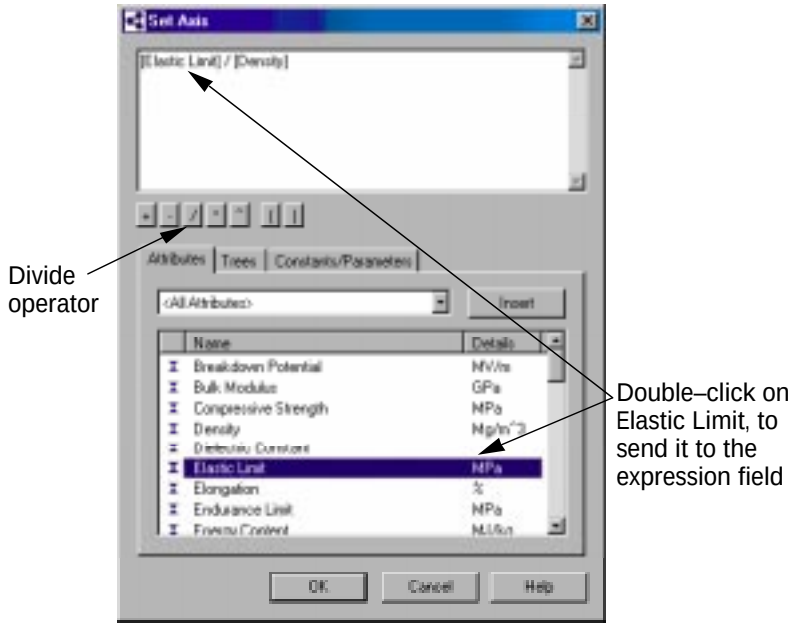

Fig. 5.25 Generating the 'user–defined' property σ_{el}/ρ for Y-Axis.

The selection chart will look like figure 5.26. The columns represent the various classes of materials (metals, polymers, etc), and each coloured bar represents the range of values of the property 'Strength/Density' = σ_{el}/ρ for one material.

The only selection option that works for bar charts is the 'box' selection. Select materials with $\sigma_{el}/\rho > 200$ MPa/(Mg/m^3) as follows:

Click once on the *Box selection* button on the *Project* toolbar

Select materials with Strength/Density > 200 by drawing a box around the area shown in figure 5.26.

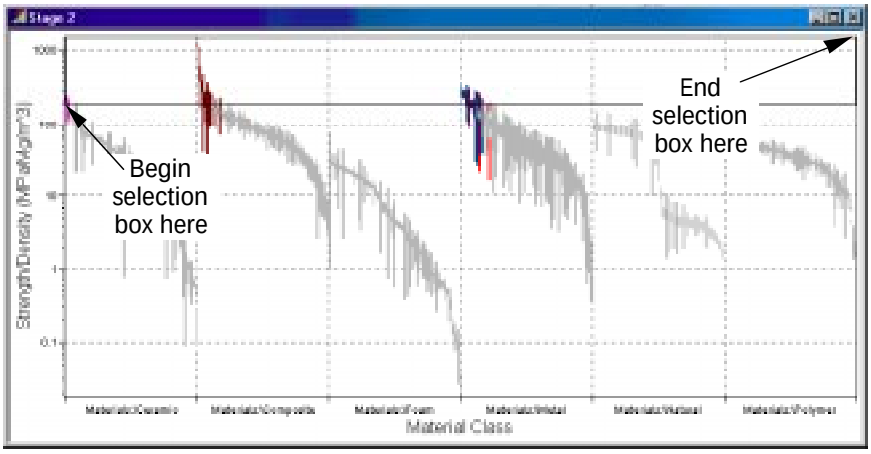

Fig. 5.26 Bar chart of σ_{el}/ρ vs. material Identifier.

5.6.4 Selections using Functional Attributes

Selections can be performed using functional attributes in almost the same way as for other numerical attributes. The only difference is that it is necessary to specify the parameters to be used when interpolating the function. For example, if you wish to select a material based on its fatigue strength, it is necessary to specify the number of loading cycles (eg $N = 10^7$) and the stress ratio (eg $R = -1$)... (See Section 5.3.4 for details of the Fatigue Strength Model.) To perform a graphical selection, proceed as follows.

Set the Filter to 'All Bulk Materials' and the Form to 'Metal'

Begin a new graphical selection stage

Select Density for the X-Axis of the chart

Select 'Fatigue Strength Model' for the Y-Axis of the chart

Click on the 'Edit' parameters button (figure 5.27)

You can either use the 'global' project default parameters for evaluating the functional attribute (Fatigue Strength Model), or you can define a set of parameters for use on this stage only (see Section 3.3.9). If you use the project defaults, then if these are updated at any time in the current project, this selection chart will automatically be updated.

If the 'Project Defaults' check box is checked, then:

(i) the project default parameters will be used for evaluating the function for this selection stage;

(ii) when you *Edit* the parameters (as shown on the right of Fig. 5.27), the project default parameters will be updated.

If the 'Project Defaults' check box is *not* checked, then the parameters will be used for evaluating the function for *this selection stage only*, and the default values of the parameters will not be affected.

Change the parameter values if you wish

Click on OK to exit the *Axis Parameters* dialog, and OK to plot the chart

A chart like that in figure 5.28 will appear. It shows the fatigue strength of most of the metals in the database, evaluated at $N = 10^7$ cycles and a stress ratio of $R = -1$. Material labels have been added and the zoom function used to improve the appearance.

Note on Limit Selection Stages: If you wish to perform a limit selection stage (see Section 5.5.2) using functional data, the values of the parameters used in the selection can be edited using the **Properties** button at the top of the *Limit Stage* window (figure 5.18).

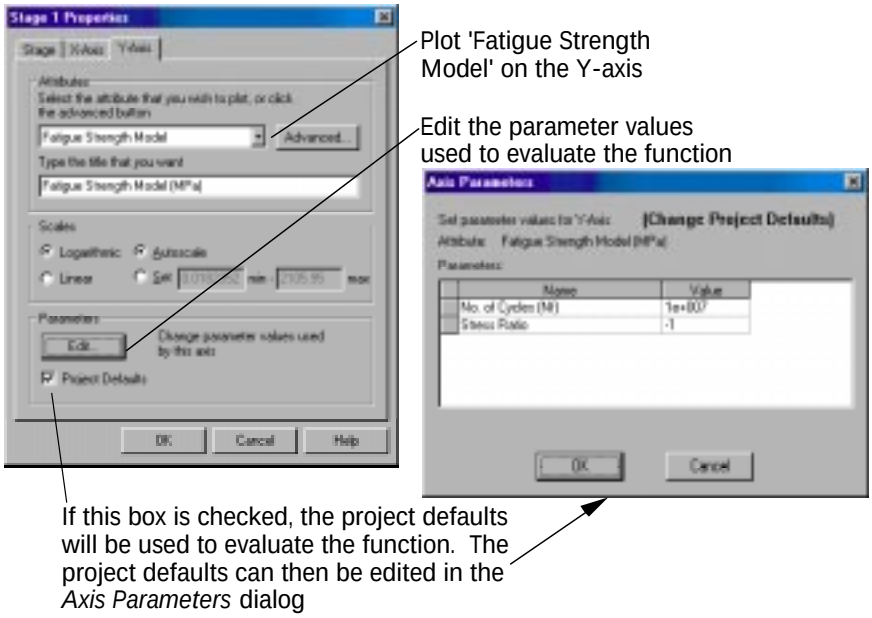
Plot 'Fatigue Strength Model' on the Y-axis
Edit the parameter values used to evaluate the function
If this box is checked, the project defaults will be used to evaluate the function. The project defaults can then be edited in the *Axis Parameters* dialog

Fig. 5.27 Setting the parameters for plotting a chart with functional data.

5.6.5 Saving Material Properties and Results

You can transfer the contents of the *Attributes* or *Results* windows to an external file as follows:

Make the *Attributes* window or the *Selection Results* window active by clicking on it (or select it from the *Window* menu).

Select *Edit/Copy* to copy the contents to the clipboard

Open another Windows™ application - such as a spread–sheet or word processor.

Select *Edit/Paste* in the external program to import the contents of the clipboard. The format of the exported data will depend on the capabilities of the external program.

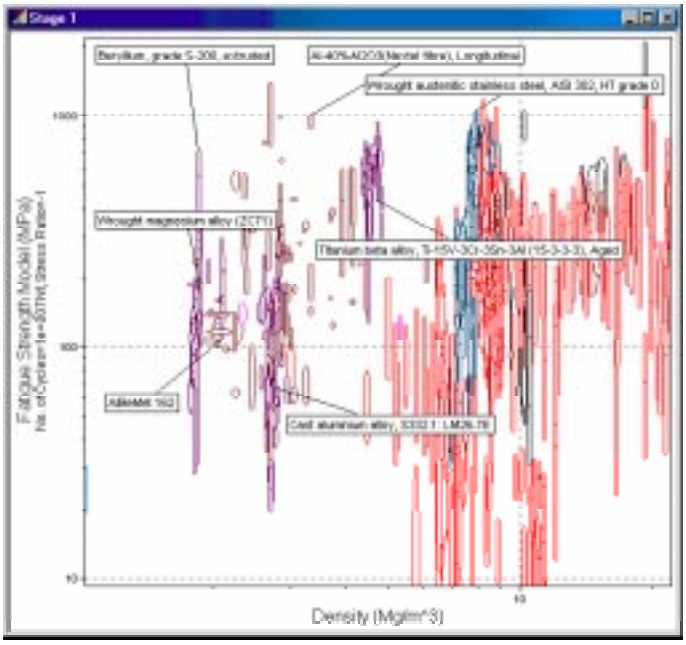

Fig. 5.28 Graph of Fatigue Strength (evaluated at $N=10^7$ cycles and R=-1) vs Density.

5.6.6 Exporting data to Finite Element programs

To export material property data to a Finite Element program:

Locate the material of interest: by clicking on a bubble on a chart, or by locating it on the Materials table tree

Select *File / Export Record*

Select the format for export in the *Export Record* dialog (figure 5.29)

Click on the *Settings* button to set the Export Settings., and choose either to output to Clipboard or to File. For export to file, specify the file name

Click on OK to exit the *Export Settings* dialog, then OK in the *Export Record* dialog to perform the export.

Notes:

(i) Only one record can be exported at a time

(ii) For the *CES* 3.2 release, the available FE file formats are for: ABAQUS, ANSYS, NASTRAN and PATRAN. Other formats may be available on request. Email: dbsupport@grantadesign.com for more details.

(iii) In all cases, the material data is assumed to be for a linear, temperature-independent isotropic material. Some of the file formats allow for the plastic behaviour of the material to be modelled, and in these cases, this information is made available for export.

(iv) Unless the file format requires a particular set of units, the data is exported in the preferred database unit system and to the current number of significant figures. It is recommended that a 'consistent' unit system is used.

(v) See further details in the on-line Help.

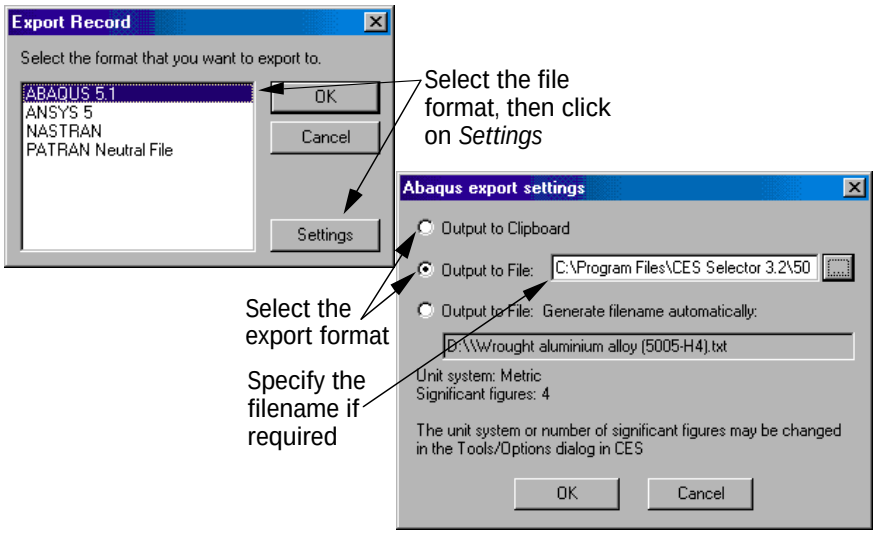

Fig. 5.29 Exporting material property data to a Finite Element program.

5.7 Concluding Remarks

This *Quick Start Guide* has guided you through some of the more important functions of *Selector*, in a rather condensed fashion. There are many more features that have not been discussed. You can learn more about the program by going through the Tutorials in the on-line Help system (see section 5.2.3) or by reading the User's Reference, in the Help system, which discusses all of the commands, buttons, windows and dialog boxes in detail.

We recommend strongly that you also read about the selection methodology underlying *Selector* in the Background Reading section of *CES InDepth*. But first, you might like to explore the system a little, to become familiar with the features that have been introduced here, and investigate others. We hope that you will find the remaining features intuitive and easy to discover and use.

PART 3
CONSTRUCTION

Chapter 6 Selection Database Design

6.1 Introduction

In order to perform *optimal selections* from a database of entities, it is necessary for the database to satisfy some important requirements. *CES Constructor* has been designed specifically to help user's make such databases. This part of the manual describes the reasons for these requirements and gives some general background into selection database design principles.

6.2 Database Taxonomy and Attributes

Systematic selection starts with a definition of the *kingdom* of entities from which the choice is to be made. Figures 4.1 to 4.3 illustrate how the kingdoms of *Materials*, of *Manufacturing Processes* and of *Structural Sections* can be subdivided into families, classes, subclasses and members. Other kingdoms of engineering entities have similar hierarchical structures, eg standard components [1][7].

Each member of the kingdom is characterised by a set of *attributes* which include: identifying information; numeric data, text, and graphical information. Take materials as an example (figure 4.1). Its kingdom contains the family '*Metals*' which in turn contains the class '*Aluminium alloys*', the sub-class '*5000 series*' and finally the particular member '*Alloy 5083 in the H2 heat treatment condition*'. This material, and every other member of the materials kingdom, is characterised by a set of attributes: its density, moduli, strength, thermal, electrical and chemical properties. Attributes are a key part of selection. They are discussed more fully below.

An important feature of a well-ordered hierarchical classification is that the properties of its members lie within ranges defined by their sub-class; the properties of all sub-classes lie within ranges defined by their class; and so on up the tree, as shown schematically in figure 6.1. In this way it is possible to create a 'generic' record at any level of the tree, which has properties that span the range of all entities below it in the hierarchy. This facilitates development of a *comprehensive* top level screening database, in which a limited number of classes or sub-classes of entities can be used to represent all members of the kingdom. This feature also facilitates data validation and checking, as explained later.

Quantitative engineering attributes are normally best stored as a *range* of values (see Section 3.3), since there is always some tolerance associated with the information. In the record for a specific material, the ranges describe the permitted or expected spread, or the experimentally–found latitude in the value of each attribute.

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[7] Numbers in parentheses [ ] refer to references listed in Appendix E.

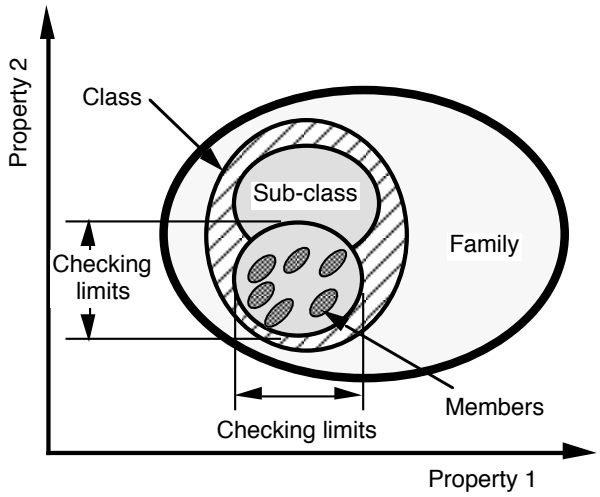


Fig. 6.1 Schematic relationship between database hierarchy and property (attribute) ranges.

6.3 Comprehensiveness

By *comprehensive*, we mean that the database contains *all* general families of entities in the kingdom of interest. Databases need to be *comprehensive* if they are to yield an *optimal* selection for every application... A materials database should therefore contain *all* families of materials in the 'materials kingdom' (metals, polymers, ceramics, natural materials and composites) [2]. A database of bearings should contain all families of bearings (Hydrodynamic, Rubbing Plain, Porous metal, Rolling element...), and so on. If it fails to do this, one or more important families of entities may be overlooked completely, ruling them out of the selection by default.

It is often tempting for engineers to assume that the best solution will be the one implied by previous experience – and therefore to use a *non-comprehensive* data source – for example, a catalogue containing, say, rolling element bearings. However this can inhibit innovation by inviting a non-optimal selection due to lack of familiarity/experience with alternative solutions. In this example, a plain bearing or a hydrostatic or magnetic bearing may be better suited to the particular application. Thus a *non-comprehensive* database, with only a limited set of families, is poorly suited to the screening and ranking selection step (Section 3.1.1).

6.4 Universal Attributes

For effective screening, the database must be tightly structured. It is essential to store the same set of information for all 'records' (entities). This constrains the choice of 'fields' (attributes) to those which are common to all entities in the database. We will call these the 'universal attributes'. Decisions about the taxonomy of the database, (the structure of records), are strongly linked to the choice of attributes.

For example, consider constructing a database of manufacturing processes. It is possible to include all of the main families of processes (casting, deposition, deformation, composite forming, rapid prototyping,...) as records in a *comprehensive* 'generic' database (as in the *CES* process data module Section 4.2). The *universal attribute set* consists of properties like 'surface roughness', 'tolerance, 'material classes', 'shape classes', 'capital cost', 'tooling cost', and 'economic batch size'. These attributes are common to *all* manufacturing processes, whatever the family and they can be used to select families, classes or sub-classes of processes from a 'generic' database of processes [3]. However, such a database should generally not contain class-specific attributes such as 'cutting rate', or 'cutting fluid type' which are only relevant to one family of processes (machining). If a 'generic' process database contained these 'family-specific' attributes, and a selection was based on them, some families (eg casting, rapid prototyping, etc) would fail the selection by default, because they would not possess data for those attributes.

6.5 Two-step Screening and Ranking Process

This requirement of common attributes generally leads to the need for a *two-step* screening and ranking process, whereby, in the first step, a *comprehensive* database is used to select the main *families* and *classes* of entities in the kingdom, based on the universal attribute set – surface roughness, tolerance etc in the process example. When one or more suitable candidates has been found, a 'family-specific' database can be used to narrow down the selection to one or more particular entities.

The family-specific database *can* contain attributes that are only relevant to the particular family of entities (eg cutting rate in a machining processes database) and these can be used in the second step of the screening and ranking process, without eliminating any candidates by default. Note however that even class-specific databases should only contain attributes that are common to all of the entities they contain. Otherwise, members may be rejected because of an absence of data.

6.6 Forms and Filters

The first step of the two–step screening and ranking process is achieved in *CES* by using the 'Generic' form and 'All Bulk Materials' filter (see Section 3.2.6 and 3.2.7). The All Bulk Materials *filter* includes *all classes* of materials used in engineering applications The Generic *form* presents only those attributes that are *universal* for all classes of materials.

During the second step of the process, once the general class of entities has been selected, a class specific form and filter can be used (eg 'polymers' for materials selection). The *filter* restricts the materials under consideration to one class (all polymers), and the *form* presents all the properties that are relevant for that class. For example, the polymers form contains 'water absorption' and 'heat deflection temperature' (a measure of creep performance) etc, in addition to the generic universal attribute set. When the polymers form is in use, selections can be made using these class–specific properties.

6.7 Completeness

All of the records in the screening database must be *complete*, ie have no 'holes' or 'gaps' with missing data. Otherwise, the inevitable consequence is that some entities will fail selections because they have no data for a particular field.

There are two main reasons why data may not be available for a particular property. The first is that the property may not strictly apply for the particular entity. The second is that it may never have been measured, or the information may not be in the public domain.

A partial resolution of this problem lies in technology for estimating attributes. There are some powerful ways of doing this for *materials* data, using relationships between properties [4]. For example, the Young's Modulus E of an isotropic material is related to its Bulk modulus K and Poissons ratio ν by the equation: $E \approx 3(1 - 2\nu)K$. So if E and ν are known, K can be predicted confidently. Similarly, if the atomic volume V_m and the melting point T_m are known for a material, then the Young's modulus E can be estimated using $E = CRT_m/V_m$, where R is the general gas constant, and C is a constant that depends on the class of materials. More details are provided in [4].

It is essential that such *estimates* in the database are flagged in some way, so that if the material is selected on the basis of one of these properties, the engineer knows to seek further information to check the estimated data. An estimate flag can be set for each estimated attribute using *Constructor*.

6.8 Data Quantity and Precision

The screening and ranking stage will in general consider a relatively small proportion of the total information available about a particular 'kingdom' of entities. The remaining information will not be in a suitable format for the screening process and will generally be better suited to the 'supporting information' step. The data will often be of low to medium precision, compared with the high precision data available later in the process. For example the price of a material or its strength stored in a general materials database may often be less precise than information provided directly by the supplier during the 'supporting information' step. However, the less precise information can be used very effectively for screening and ranking purposes.

6.9 Choice of Fields

The fields chosen for a selection database must satisfy three criteria: *comparability*, *measurability* and *discrimination*.

6.9.1 Comparability

The importance of storing a common set of universal attributes in the screening database was mentioned in section 6.4. It is necessary to choose these attributes so as to ensure *comparability* of entities. A difficulty arises when the kingdom contains many families: it is that, for reasons of history and convenience, a single attribute may be measured in several different ways. Consider, for example the *hardness* of materials. The hardness of metals is measured on the Rockwell, Vickers or Brinell hardness scales; that of elastomers is measured on the Shore or Durometer scale; that for minerals on the Moh

scale. They are measured with different testing equipment, reported in different units, and there are no simple relationships between them. However, since all material have a hardness, it is an important attribute in a *comprehensive* materials database. This creates the necessity to choose a common equivalent hardness scale – the Vickers scale, say – for all materials, and to calculate or estimate suitable values for those materials that are not usually measured on that scale.

Family-specific or class-specific databases *can* contain attributes which are not universal to the kingdom, as long as they are common to all members of the family or class. Thus a database of elastomers could contain the Shore hardness - and this could be used to screen at the family or class-specific level. Similar problems are found in databases of manufacturing processes and of components, and can be resolved in a similar way.

It is sometimes useful to create universal attributes which summarise various types of behaviour into a single quantity. An example of this is the 'maximum service temperature' of a material, defined as "the highest temperature at which the material can reasonably be used in a load-bearing component, without oxidation, chemical change, or excessive creep becoming a problem" [5].

6.9.2 Measurability

There are standard ways of measuring many engineering properties: density, modulus, thermal conduction and dielectric properties are examples. There are other properties - some microstructural, others relating to corrosion in exceptional environments or to tribological behaviour, which one might like to use for screening, but their use in this function is precluded by lack of data and the near-impossibility of making any sensible estimate.

6.9.3 Discrimination

The choice of attributes for screening must allow discrimination between entities. Thus density, modulus and strength are discriminating attributes when the kingdom is that of *materials*; but if the kingdom is restricted to the family of carbon steels, density and modulus cease to be discriminating because all carbon steels have almost the same values of these properties. Strength, hardness, and magnetic coercive force (a property which is non-universal for the greater kingdom of materials but universal for carbon steels) are all discriminating in the family-specific case.

6.10 Data Checking

The value of a database depends on its accuracy and its completeness – in short, on its quality. One way of maintaining or enhancing quality is to subject the data to validating procedures. The range-checks and physically based correlations, described below, provide powerful tools for doing this. The same procedures fill a second function: that of providing estimates for missing data. This is essential when direct measurements are not available [4].

6.10.1 Range Checks

Trivial though it may seem, it is valuable, when creating a database, to tabulate the known range of values of each attribute for each class in the database, and to check whether each new datum lies within the appropriate range. A convenient way of

presenting the information is as a table in which a low (L) and a high (H) value are stored, identified by the family or class.

If the attributes of the records at each level of the hierarchy (table tree) are chosen to be an envelope of the attributes of the records beneath them in the hierarchy, then the attributes of new records added to the database can be checked against the envelope of attributes representing their peers, as shown in figure 6.1.

As an example, consider a new aluminium alloy that is being added to the database, 5678-T6. Its attributes can be expected to lie within the envelope of attributes defined for all 5000 Series Aluminium Alloys, which in turn can be expected to have attributes typical of 'Wrought Aluminium Alloys', which will have attributes with the envelope of the record 'Light Alloys', which will have attributes within the envelope defined by 'Metals''.

Range checks, usually based on experience or current practice, can be devised for almost any attribute of almost any entity. The use of the ranges for property checking is obvious: any new datum should lie in its proper range; if it does not, it should be checked. Why bother with such low-level stuff? Because in computations involving engineering entities, the most common error is the use of an attribute-value which is expressed in the wrong units, or is, for less obvious reasons, in error by one or more orders of magnitude (slipped decimal point, for instance). Class-specific range checks catch errors of this sort.

6.10.2 Correlations Between Attributes

Materials which are stiff have high melting points. Solids with low densities have high specific heats. Metals with high thermal conductivities have high electrical conductivities. These rules-of-thumb describe correlations between two or more material properties which can be expressed more quantitatively as limits for the values of *dimensionless property groups*. They take the form:

$$C_L < P_1 P_2^n P_3^m < C_H \tag{6.1}$$

(or larger groupings), where P_1, P_2, P_3 are material properties, n and m are simple powers (usually -1, -1/2, 1/2 or 1), and C_L and C_H are dimensionless constants – the lower and upper limits between which the values of the property-group lies. One example is the relationship between expansion coefficient, α (units: K^{-1}), and the melting point, T_m (units: K):

$$C_L \leq \alpha T_m \leq C_H \tag{6.2}$$

Where they exist, such correlations permit checks and estimates which are much more discriminating and precise than are the simple range checks.

For another example, consider the ratio of tensile strength to compressive strength. For most (although not all) metals, this value is close to unity, but for ceramics the value is somewhere between 0.1 and 0.3. So, whilst the entire kingdom of ceramics, from 'Plaster of Paris' up to 'Diamond' has a wide range of values for tensile strength and compressive strength, the ratio of the one to the other falls within a much smaller range.

There are other useful relationships between attributes which arise from the mechanics, thermodynamics or economics of a particular application. These can also be used profitably for data checking. A few examples follow:

• the *upper and lower bounds* on the properties of composites, which can be used to estimate or check the properties of a composite from the properties of its constituent parts;

• the *local buckling* of structural sections which can be used to estimate or check the maximum 'shape factor' of a structural section [6];

• the *buckling load* of a shaft which can be used to check the maximum force of a linear actuator;

• the *burst limit* of bearings which can be used to check their maximum rated speeds;

• the *torque* of a permanent magnet motor which is limited by its size and the remnance of the material of its magnet;

• the *economic batch size* of a manufacturing process which is related to the capital cost of the processing equipment.

• the CO_2 emissions associated with making a material, which is closely related to its energy content.

6.10.3 Automated Checking Procedures

The hierarchical structure of entities (Section 6.2) and relationships between the properties can be used profitably to automate aspects of data checking. The scheme that is implemented in *Constructor* and used in the development of the *CES* databases involves two independent checking stages as shown in figure 6.2. In the first stage, the range of every property of each member of the database is checked against the ranges stored for the 'generic' sub-class above it in the database hierarchy (see figure 6.1). Similarly the sub-class entities can be checked against the ranges stored for the classes above them, and so-on.

In the second stage of checking, the property correlations described above are checked, using the same hierarchical procedure.

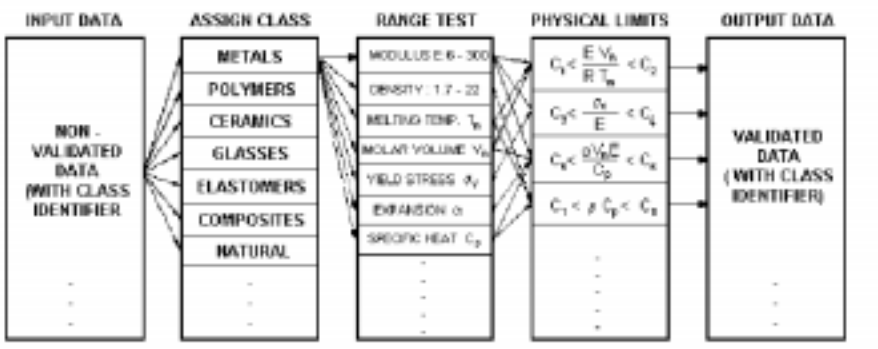


Fig. 6.2 The scheme for checking material properties in *CES* databases.

6.11 Approximations, Estimates and Non-Existence of Data

The need for *completeness*, ie the absence of holes in records for screening has already been mentioned. There are three ways of dealing with holes.

6.11.1 Approximations

An attribute may not strictly apply for the particular entity. The 'modulus of rupture' σ_{MOR} is one such property in material properties database. It describes the bending stiffness of a brittle material, like glass, and is familiar to ceramic engineers (who measure strength in this way) but not to metallurgists (who use other measures of strength). An engineer seeking a material with an adequate modulus of rupture really wants one with an adequate *bending strength* - so a practical solution is to fill the modulus of rupture field in the metals part of the database with a comparable property: the *yield strength*. Then metals with adequate bending strength will pass selections based on the modulus of rupture.

6.11.2 Estimates

In some cases the value of an attribute may not have been measured, or may not be in the public domain. Then it is necessary, for completeness, to estimate a value. Some material properties fall into this category. The *estimation of attributes* is an activity in which much is done but little is written. For material properties, usefully accurate estimation techniques exist. These are based on physical relationships between properties [4]. As discussed in Section 6.10.2, they are of primary help both for estimating and checking attributes.

Process attributes and attributes of components are harder to estimate. When the entity is part of a group with which it has much in common (its 'siblings'), weighted interpolation can be used to estimate the missing attributes of one entity when those of its siblings are known [7].

It is essential that *approximations* and *estimates* in the database are flagged in some way, so that if the material is selected on the basis of one of these properties, the engineer knows to seek further information to check the estimated data. Such flags are easily set in *Constructor*.

6.11.3 Non-existence of Data

There are some (rare) attributes which need to be stored in a screening database, but are not common to all entities in that database. They are therefore exceptions to the *universality* rule. These are best designated as 'not-applicable' in the database. They can be recognised by the fact that it would be acceptable for entities which have a 'not-applicable' entry to *fail* a selection based on that property.

Consider, for example, selecting a dielectric material for a capacitor, on the basis of its *dielectric constant*. The dielectric constant is an electrical property which is important to a 'generic' materials database, even though it is relevant and measurable only for insulators; for conductors it is non-applicable. An engineer seeking a dielectric would not wish to consider a conductor, so it is acceptable for all conductors in a generic database to have 'not applicable' entries for *dielectric constant*, and to fail selections based on it.

6.12 Relational Structures

A cardinal rule of data-base structure is that there be no redundant data. Many aspects of computerised selection can be performed adequately with the data stored in a 'flat file' (ie a table), in which the columns of the table contain the fields (attributes) and the rows contain the records (entities) - rather like a spreadsheet. For some database functions, however, flat files are inadequate and a 'relational' structure is considerably better. Consider, as an example, the 'suppliers' field in a class-specific materials database of (say) aluminium alloys. This database may contain some hundreds of different alloys, most of which are manufactured by a small number of companies (Alcan, Alcoa, AluSwiss, Pechiney, Norsk Hydro etc). In a flat file it is necessary to store the name and address details of one or more of these companies in every record, with some of the suppliers appearing in several different records. This would be a violation of the redundancy rule. Were one supplier to change telephone number, for example, then every instance of this number must be updated throughout the database, with potential for error and omission.

A *relational* database structure overcomes this problem. The simplest relational database contains two data 'tables'. In this example, one table contains material properties, the other contains information about the suppliers, as shown schematically in Figure 6.3. Each supplier appears just once in the suppliers table. The database management software creates and maintain *links* between this supplier and every material that it supplies. In a relational database the links are as important as the attributes (in fact they can be considered to *be* attributes) and they require a software system which handles them flexibly and automatically.

A powerful feature of links is that they work in both directions. Thus it is possible to use the example system as a *materials* selector to select materials that are made by particular suppliers (eg "select all aluminium alloys made by US suppliers"). Alternatively it could be used as a *suppliers* selector to select the suppliers that manufacture particular materials (eg "select all US suppliers who make aluminium alloys").

6.13 Supporting Data Tables

This chapter has concentrated on data tables which are designed for the purpose of *optimal selection*. Of course, not all data tables are used for selection. Some provide supporting information. For example, a table of preferred suppliers of materials clearly does not need to satisfy many of the requirements - of comprehensiveness, completeness, etc. It simply needs links to the relevant records in the selection table.

A useful approach is to store raw data in separate tables from design/selection data. For example, it is possible to store laboratory test data in a raw data table, and to generate a selection data table by processing the raw data - eg by statistical analysis of multiple test records. Records in the raw and selection data tables can be linked together in the normal relational way. The selection data table can be used to compare materials through summarised properties and to perform optimal selections. Then, by viewing the linked records in the raw data table, the user can find out about the source and pedigree of the selection data.

This is the approach used by Granta Design for many databases. For example the raw data in MIL-HDBK-5 and 17 is not suitable for selection purposes because it is not

complete - it is full of gaps. The core CES materials table has a record for each of the MIL-HDBK materials, which *is* complete. These records have data for the *universal attributes* only - not for the specific MIL-HDBK data. The gaps have been filled using non MIL-HDBK data for some properties. This table can be used very effectively to compare and select MIL-HDBK materials at a generic level. It is then possible to link to specific MIL-HDBK records and view/manipulate/plot all of the approved MIL-HDBK data.

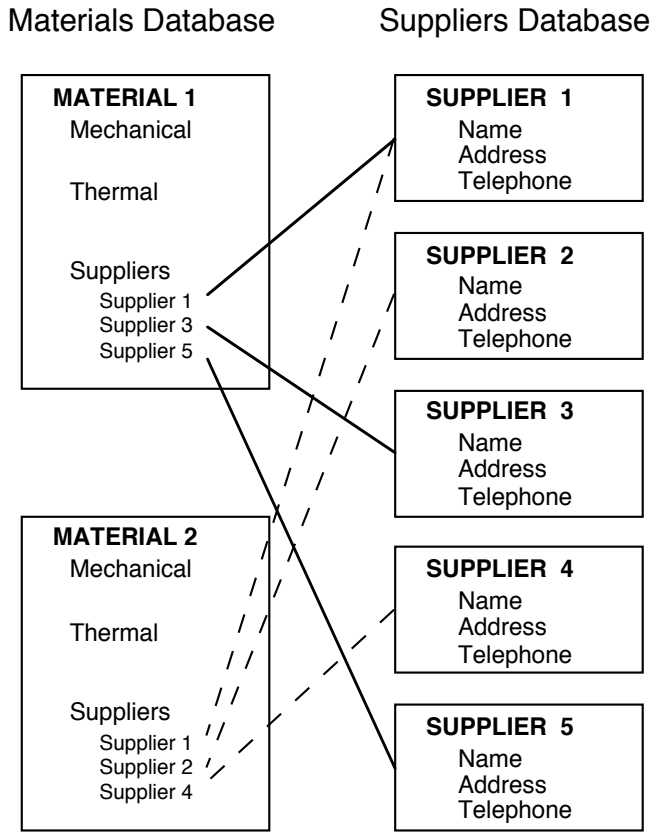


Fig. 6.3 Relational structure of material and supplier data tables.

6.14 Conclusions

Optimal selection of standard engineering entities, whether performed on paper or a computer screen, is best achieved by a two-step process: a 'screening and ranking' step followed by a step of 'supporting information'. In the first step the kingdom of entities is reduced to a small candidate list which meets the attribute limits and maximises optimising indices. The second step retrieves detailed contextual information about each of the candidates and enables a final choice to be made.

(i) A database suitable for *screening* should have the following characteristics:

- It should be *comprehensive* – contain all general classes of entities in the 'kingdom' of interest.
- The attributes it contains should be *universal* – common to all of the entities in the database. The attributes should further satisfy the requirements of *comparability*, *measurability* and *discrimination*.
- It should be *complete* – have no holes or gaps without any data. This can be achieved by the use of *approximations* and *estimates* to fill the holes.
- It should have a *relational* structure (or similar), to minimise data redundancy.
- It should, where possible, exploit a *hierarchical* taxonomy, so as to facilitate data checking between layers of the structure.
- Range checks and physically-based relationships between the attributes should be used to implement automatic data checking procedures.

(ii) The *supporting information* system can have information stored in any format. The only requirement is that items of information should be 'tagged' according to the identifiers of records in the screening database. Once a particular entity has been isolated by the screening process, all information about it can be retrieved rapidly from the supporting information system.

Taken together, the two-step selection process is capable of selecting an 'optimal' entity from a kingdom containing many thousands of entities. Successful examples exist in the fields of materials [8], processes [9], section shapes [10] and components [1, 11, 12]. This architecture is the core of the *CES* system.

Chapter 7 Constructor Quick Start Guide

7.1 Introduction

This *Quick Start Guide* provides a brief overview of the facilities of *CES Constructor*. It does not offer step–by–step instructions on how to run the program, and is not comprehensive in its coverage of the facilities in *Constructor.* It assumes that you are familiar with running programs under the Windows™ operating system, and are experienced with the concepts underlying the *CES* system. If you are not familiar with use of *CES*, it is recommended that you work through the *Selector Quick Start Guide* in Chapter 5, of this manual *before* beginning work with *Constructor*. For detailed instructions on all aspects of *Constructor*, see the on-line Tutorials in the *CES Constructor* Help system.

The fundamentals of selection database design are discussed in Chapter 6. Although it is not necessary to read that information before you work through this chapter, it is strongly recommended that you do before beginning any large selection database design project.

This *Constructor* Quick Start manual has four main sections:

Section 7.2 – Editing Attributes	explains how to edit the attributes of an existing record and how to use the automatic data checking.
Section 7.3 – Adding Records	Shows you how to add a new record to the database and add links between records.
Section 7.4 – Creating Components	demonstrates how to create discrete attributes and new units.
Section 7.5 – Creating a New Table	explains how to create a new table and define its structure, as well as how to create forms and filters.

Before starting this *Quick Start* Guide, you will need to install the *CES system* by following the instructions in Chapter 2 of this manual.

Note that the *CES Constructor* software is not automatically distributed with every *CES* system. It will only be available if you have purchased a licence for *Constructor*.

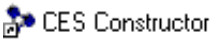
7.2 Editing Attributes

In this exercise, you will learn how to edit a record and how to use the automatic data checking system.

7.2.1 Open the 'Starter' Database

The installation process will make a Start Menu Programs group called 'CES Selector 3.2', which will contain the icons for *CES* software components, as shown in figure 2.7.

Double-click on the *CES Constructor* icon to run the program



You can also access the *CES Selector* Start Menu Programs group on the **Programs** option on the **Start** menu (usually at the bottom left of the Windows™ screen).

The exercises in this quick start guide are based on a small 'starter' database called 'starter1.gdb'. This should be located in the 'Samples' folder of the *CES* installation directory. In a single user installation of the software, the default location for this file is: C:\Program Files\CES Selector\Samples\Database. We recommend that you make a backup copy of this database file before your begin. (Do this using the normal facilities of Windows Explorer). Then...

Select the *Open database* option on the *File* menu (File/Open database) or click once on

Find the sample databases directory using the options in the *Open Database* dialog box (eg C:\Program Files\CES Selector 3.2\Samples\Database):

Open the database 'Starter1.gdb'

7.2.2 The Control Window

Operation of *CES Constructor* centres around the *Control* window, shown in figure 7.1. It has three tabs along the top. The first of these 'Database' provides general information about the current Database. From this window you can perform operations on the overall structure of the database, define the attributes contained in individual tables and edit the 'forms' and 'filters' associated with each table (see Sections 3.2.6 and 3.2.7). The second tab 'Tables' has a drop-down list of tables, just like the *Project* window in *Selector*. The *Books* tab opens the on-line book (default *CES InDepth*).

Open the material record 'Cast magnesium alloy AM60' as follows:

Select the *Materials* table from the list box on the *Tables* tab

Open the materials tree as shown in Figure 7.2, by clicking once on the '+' symbols, to display the contents of some of its branches.

Note that the branches of the tree (or 'folders') are indicated by various different icons explained in Section 3.2.4.

Double-click on 'Cast magnesium alloy AM60'

Scroll through the record until the Mechanical properties are visible, (Fig. 7.3).

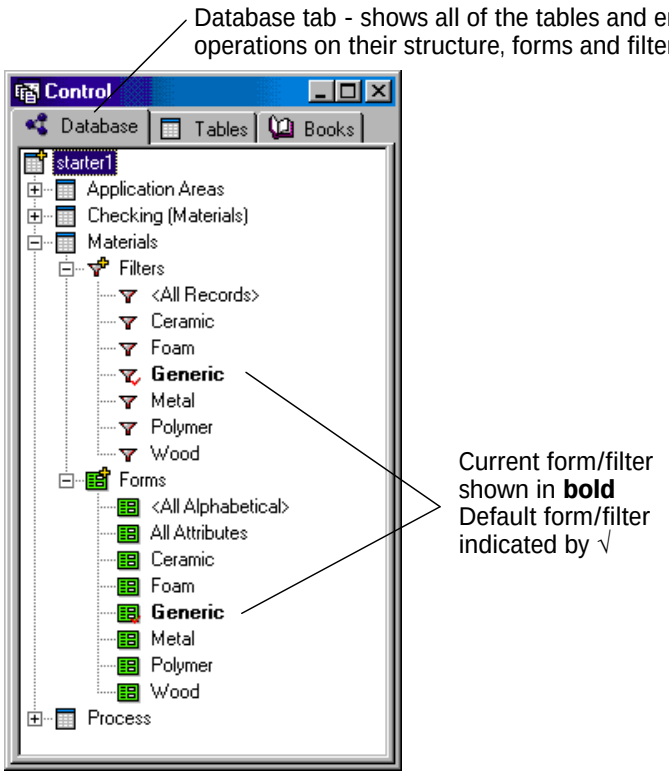


Fig. 7.1 The *Control* window

7.2.3 The Attributes Window

The information displayed for the material in the *Attributes* window (figure 7.3) is similar to what you would see in *Attributes* window in *Selector*. The numbers in the white boxes are range attributes which can be edited. The buttons down the right side of the window are the data checking buttons. The green tick marks indicate that these attributes have all passed their automatic data checks. (The concepts behind the automatic data checking are described in Section 6.10.3.) The blue symbols in the second column from the right indicate that some attributes are uncertain or estimated.

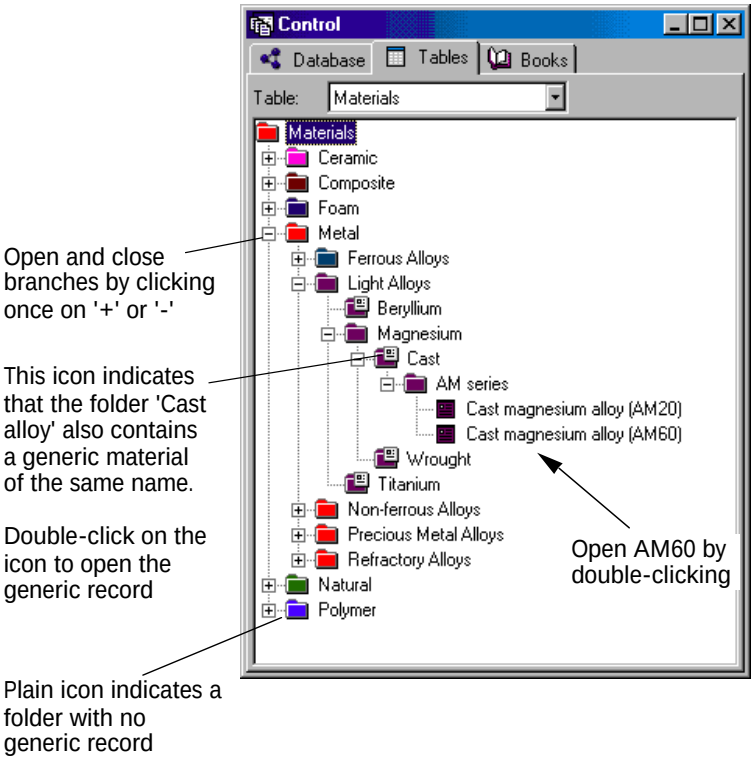


Fig. 7.2 The *Materials* tree in the *Control* window.

7.2.4 Checking Material Attributes

Examine the operation of the automatic data checking as follows:

Change the values of *Elastic Limit* (yield strength) to: 330 to 340 MPa (then click outside of the edit box)

The checking button beside *Elastic Limit* will become a red cross ✕, which indicates that this attribute lies outside its checking range. (For cast magnesium alloys, including AM60, the elastic limit should lie in the range of 65 to 210 MPa.)

Click on the checking button for *Elastic Limit* ✕

The *Checking* window will appear. Near the top of the window are fields which show that the check record is called 'Cast magnesium' and it is located in the table called '*Checking (Materials)*'. (The *check record* contains the values that are being used to check the data in the AM60 record.) The first line in the body of the record states that the value of the *Elastic Limit* in the AM60 record lies out of the range 65 to 210 MPa[8].

Return to the *Attributes* window

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[8] The checking process compares the *geometric mean* of the range of properties ($\sqrt{330 \times 340} = 335$ MPa) with the range in the checking record (65 to 210MPa).

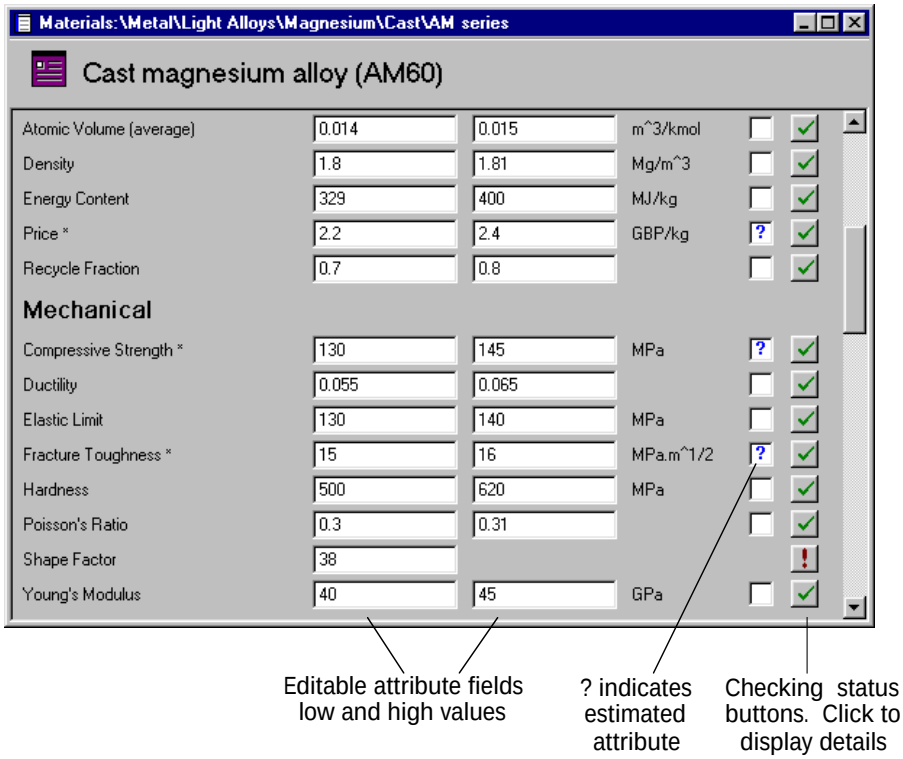
Materials:\Metal\Light Alloys\Magnesium\Cast\AM series
Cast magnesium alloy (AM60)
Atomic Volume (average) 0.014 0.015 m^3/kmol
Density 1.8 1.81 Mg/m^3
Energy Content 329 400 MJ/kg
Price * 2.2 2.4 GBP/kg
Recycle Fraction 0.7 0.8
Mechanical
Compressive Strength * 130 145 MPa
Ductility 0.055 0.065
Elastic Limit 130 140 MPa
Fracture Toughness * 15 16 MPa.m^1/2
Hardness 500 620 MPa
Poisson's Ratio 0.3 0.31
Shape Factor 38
Young's Modulus 40 45 GPa
Editable attribute fields low and high values
? indicates estimated attribute
Checking status buttons. Click to display details

Fig. 7.3 The *Attributes* window.

In the *Attributes* window, the green tick next to *Compressive Strength* for AM60 has also changed into a 'tick and cross' symbol. This indicates that *Compressive Strength* has passed its range check, but failed one or more 'consistency' or 'correlation' checks with other attributes.

Click on the checking button for Compressive Strength

As shown in figure 7.4, even though the values of *Compressive strength* are within a suitable range, they are no longer *consistent* with the values of *Elastic Limit*. The ratio of these two attributes should be near to one for a ductile metal: ie the strengths in tension and compression should be quite similar.

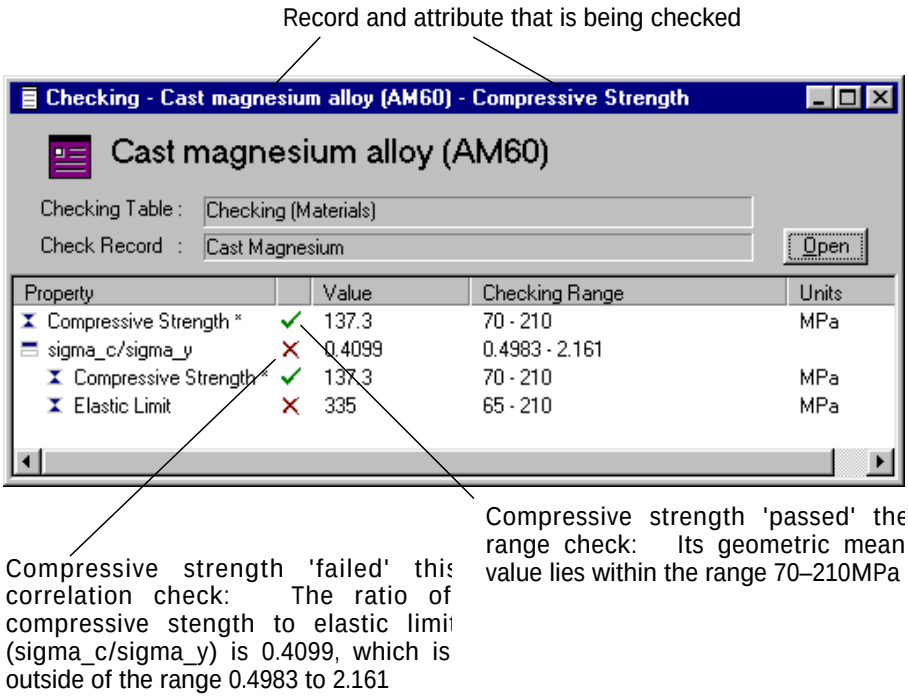

Fig. 7.4 *Checking* window showing that Compressive Strength passed its range check, but failed its correlation check with Elastic Limit.

7.3 Adding Records

7.3.1 Tree Codes

The *CES* 'tree codes' or record identifiers provide a consistent designation system which applies to all entities in the database. The designations consist of a set of letters and numbers, as explained in Section 3.2.5.

Open the *Tools/Options* menu

Click once in the 'Show Tree Codes' box, then click on OK to exit.

The tree codes will appear on the material tree in the *Control* window, and in the header of the *Attributes* window. Here the identifier for AM60 is shown as 'MMLAMGC_AM001'. This can be translated by viewing the codes on the branches of the materials tree above AM60: Metal (MM) – Light Alloys (LA) – Magnesium (MG) – Cast (C_) – AM Series (AM) – Specific alloy AM60 (001).

Close the *Checking* window and close the *Attributes* window for AM60

7.3.2 Adding a Record

Create a new material branch below 'Cast' magnesium, containing materials in the 'EQ' alloy series.

Use the right mouse button to click on the 'Cast (C_)' icon . Select 'New >' from the context menu then 'Folder' using the left mouse button (figure 7.5)

In the *New Folder Wizard*:

Enter the Short Name 'EQ Series'
Enter the Full Name 'EQ Series Cast Magnesium Alloy'
Enter the Short Code (tree code) 'EQ'
Change the tree colour if you like
Click on 'Next >' to move to the next page of the Wizard
Check the boxes to add the material to the 'Generic' and 'Metals' filters
Click on Finish

Create a material record under the new 'EQ Series' branch as follows:

Either: Right mouse click on 'EQ Series', then Select 'New >' and 'Record'

or: Left mouse click on 'EQ Series' and Click on the New Record button on the toolbar **;**

or: Left mouse click on 'EQ Series' and select the menu option *Database/New Record*

In the *New Record Wizard*:

Enter the Short and Full names 'Cast magnesium alloy EQ21'
Enter the Short Code '001'
Add the material to the 'Generic' and 'Metals' filters

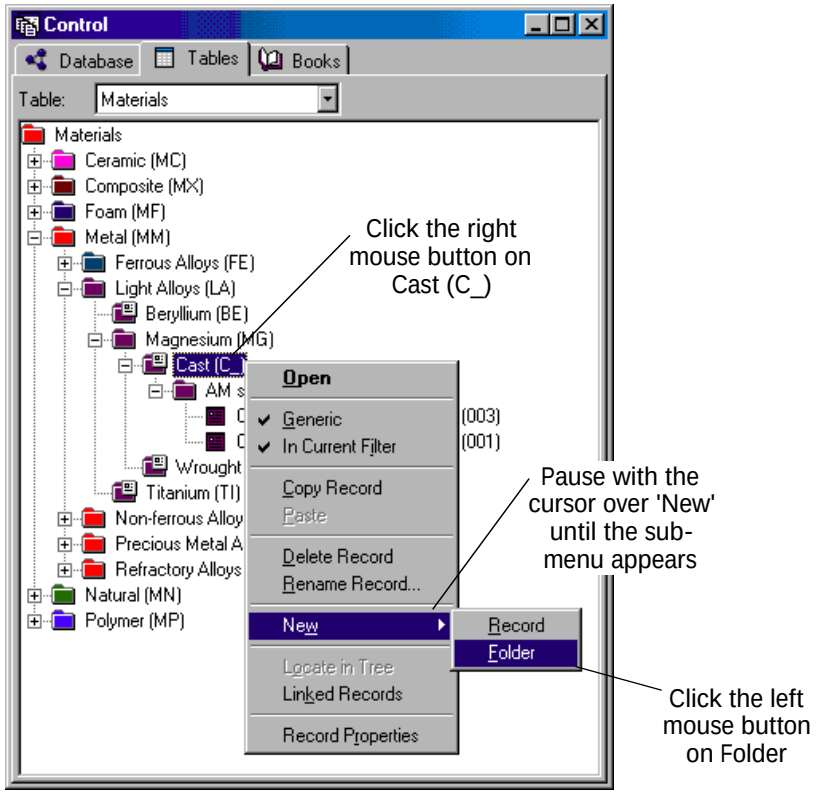

Fig. 7.5 Adding a new material folder below Cast in the Materials tree.

Open the record for EQ21 in the *Attributes* window:

Either: Double-click on the icon of EQ21 in the materials tree;

or: Right-click once on EQ21 in the table tree, and select 'Open' from the context menu;

or: Left-click once on EQ21 in the table tree, and select the menu option *View/Record Attributes.*

Enter some of the attributes of EQ21 into the *Attributes* window, as shown in figure 7.6 (you needn't enter them all). Click the estimate button to the right of a property to toggle the 'estimate' flag on and off as needed (eg for 'Price').

Scroll down the window to the section headed 'Environmental Resistance'

Click once in the field next to 'Flammability' and select the option 'Average' from the drop-down list. (This is a 'discrete' property).

Enter some text into the 'Typical Uses' field

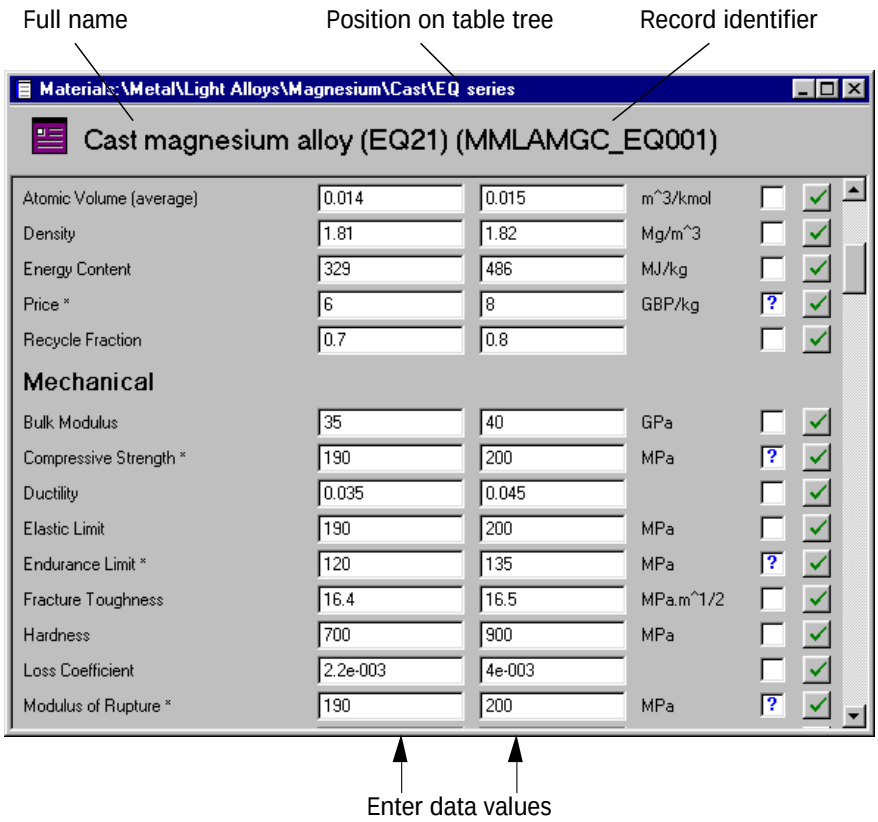
Full name
Position on table tree
Record identifier
Materials:\Metal\Light Alloys\Magnesium\Cast\EQ series
Cast magnesium alloy (EQ21) (MMLAMGC_EQ001)
Atomic Volume (average) 0.014 0.015 m^3/kmol
Density 1.81 1.82 Mg/m^3
Energy Content 329 486 MJ/kg
Price * 6 8 GBP/kg
Recycle Fraction 0.7 0.8
Mechanical
Bulk Modulus 35 40 GPa
Compressive Strength * 190 200 MPa
Ductility 0.035 0.045
Elastic Limit 190 200 MPa
Endurance Limit * 120 135 MPa
Fracture Toughness 16.4 16.5 MPa.m^1/2
Hardness 700 900 MPa
Loss Coefficient 2.2e-003 4e-003
Modulus of Rupture * 190 200 MPa
Enter data values

Fig. 7.6 Attributes of Cast Magnesium Alloy EQ21.

7.3.3 Adding Links Between Records

Link this material to some manufacturing processes as follows:

Scroll to the bottom of the record to the section headed 'Links'

Click once on the 'Process' link button ...

The *Links* window shown in figure 7.7 will appear. Note that the list box at the top of the window is set to the *Process* table – but this can be changed if you want to generate links between EQ21 and other tables.

Open the Machining branch of the process links tree as shown in figure 7.7.

Check the box next to 'Fine Machining' to create a link.

Notes:

(i) Prior to the creation of this new link a number of other process categories were already linked automatically. For example, the Casting and Deposition branches and the Machining/Polishing branch of process tree were all linked. This is because there are links in the Starter1 database between some 'parents' or 'grand

parents' of EQ21 (eg 'Cast Alloys', 'Magnesium' or 'Light Alloys') and some manufacturing processes. EQ21 'inherited' these (indirect) links from its parents.

So if every member of a material class can be processed in a particular way, (eg all 'Cast Magnesium alloys' can be processed by 'Casting') it is not necessary to link every material individually. It is only necessary to link the parent record 'Cast Alloys' to the process 'Casting', and all the members of the Cast alloys family will inherit this link.

(ii) When the direct link to 'Fine Machining' was created, the parent process 'Machining' was linked automatically. This enables selections to be made using the link to 'Machining' or to 'Fine Machining' – either of which would be a valid choice.

See Section 8.1 for a more detailed discussion of the linking process.

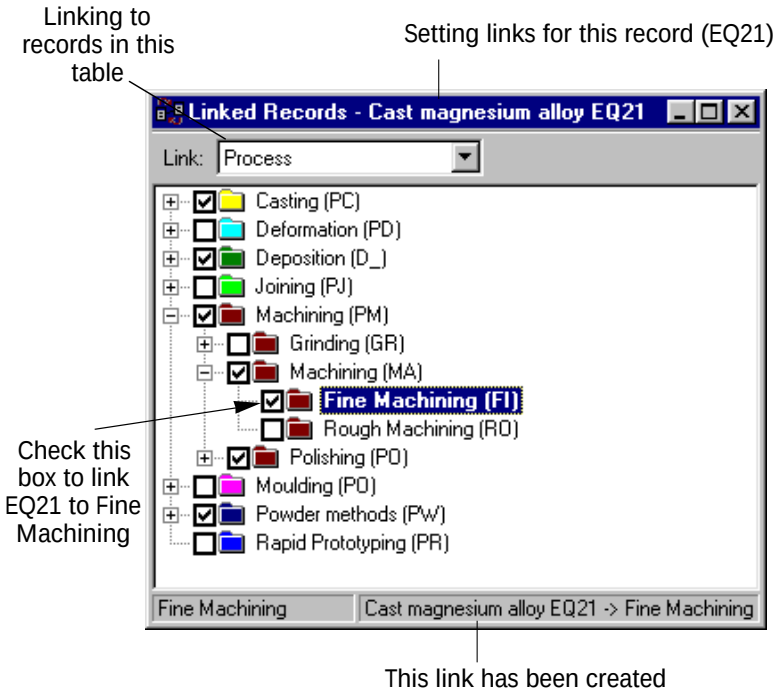

Fig. 7.7 Creating a link between EQ21 and the process 'Fine Machining'.

7.3.4 A Note about Properties and Attributes

Data records in Granta databases contain two sorts of data, record 'properties' and record 'attributes'.

Each record and each folder in a *CES* database has a set of 'properties' – just like a file or folder in Windows Explorer. These properties contain information about the name of the record, its location on the tree, which record filters it belongs to, etc. The properties

are set by the *New Folder/Record* wizard (with some input from the user) when each new record is created. See Section 7.3.2.

Each record in the database also has a set of 'attributes'. The attributes are the data values eg, the Young's modulus of a material. The attributes are all user-defined.

7.4 Creating Table Components

This section explains how to create two components that are needed for building a table of material suppliers (which is the subject of Section 7.5). These are a *discrete* attribute type, with the settings 'High', 'Medium' and 'Low'; and a new unit called tonnes (metric tons).

7.4.1 Discrete Attributes

Create a discrete attribute called '3-value' as shown in figure 7.8:

Select the menu option *Database / Database Properties*

Click once on the 'Discretes' Tab of the *Database Properties* dialog

Create a new Discrete property type by clicking on the *New* button near the top right of the dialog box (under 'Discrete Types')

Edit the name of the new discrete property to '3-value'.

Ensure that '3-value' is highlighted, then create its values by clicking once on the *New* button in the middle of the dialog box, (under 'Discrete values')

Edit the name of the new value to 'High'

Repeat the process to create values 'Medium' and 'Low'

Click once on *Apply* at the bottom of the dialog box.

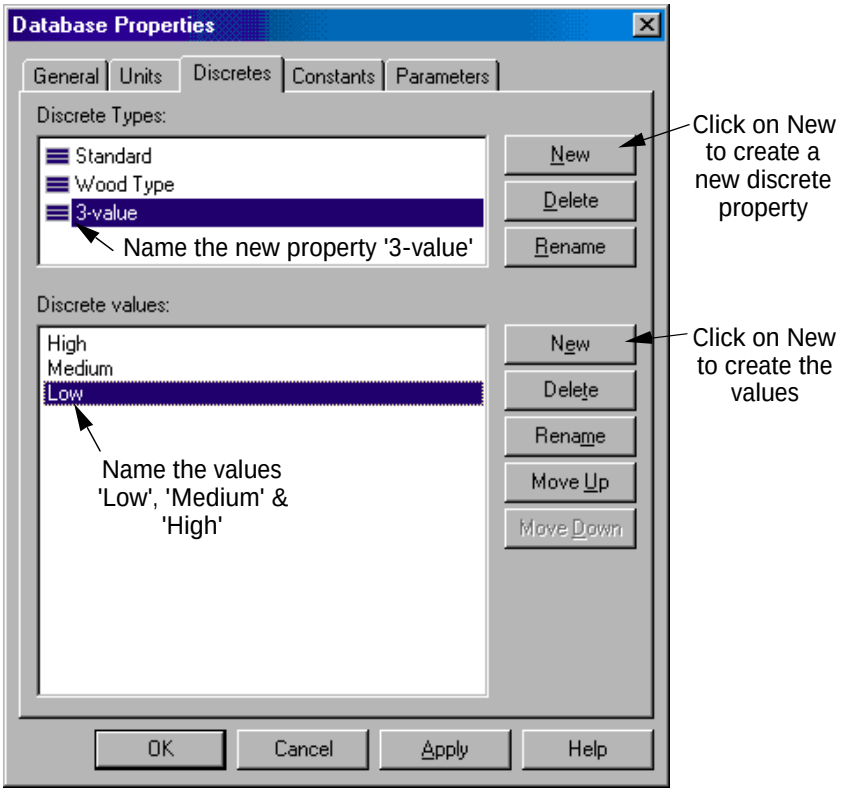

Fig. 7.8 Creating a new discrete property in the *Database Properties* dialog box.

7.4.2 Creating Units

Now create a new unit called 'tonnes' (Metric tons) as shown in figure 7.9. (Note that starter1.gdb already contains many different unit types and their conversion factors.)

Click on the 'Units' tab at the top of the *Database Properties* dialog box.

Click on the *New* button to create a new unit. The *Unit Settings* dialog box will appear (figure 7.9).

Enter the name of the new unit 'Metric ton' and its symbol 'tonne'

Click on the *Settings* button (under 'Conversions') to set conversion factors.

Select the option 'This unit is derived from another unit' (figure 7.10), then enter the conversion factor of 1000, and select the base unit 'kilogram (kg)' from the drop–down list box.

Click on OK to exit the *Unit Conversions* dialog

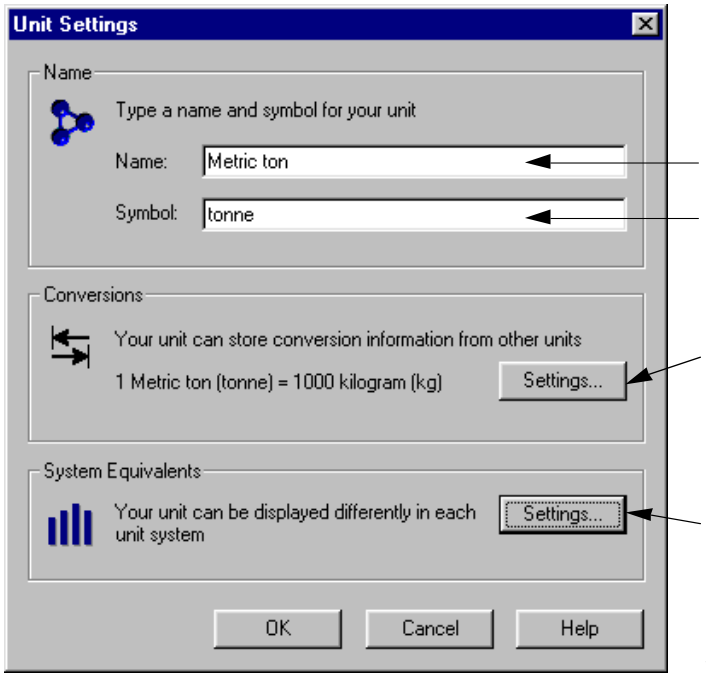
Unit Settings
Name
Type a name and symbol for your unit
Name:
Metric ton
Symbol:
tonne
Conversions
Your unit can store conversion information from other units
1 Metric ton (tonne) = 1000 kilogram (kg)
Settings...
System Equivalents
Your unit can be displayed differently in each unit system
Settings...
OK
Cancel
Help
Enter the new unit name 'Metric ton' and the unit symbol 'tonne'
Click on Conversions Settings to set conversion factors
Click on System Equivalents Settings to define equiv-alent units in various unit systems.

Fig. 7.9 Creating a new unit type.

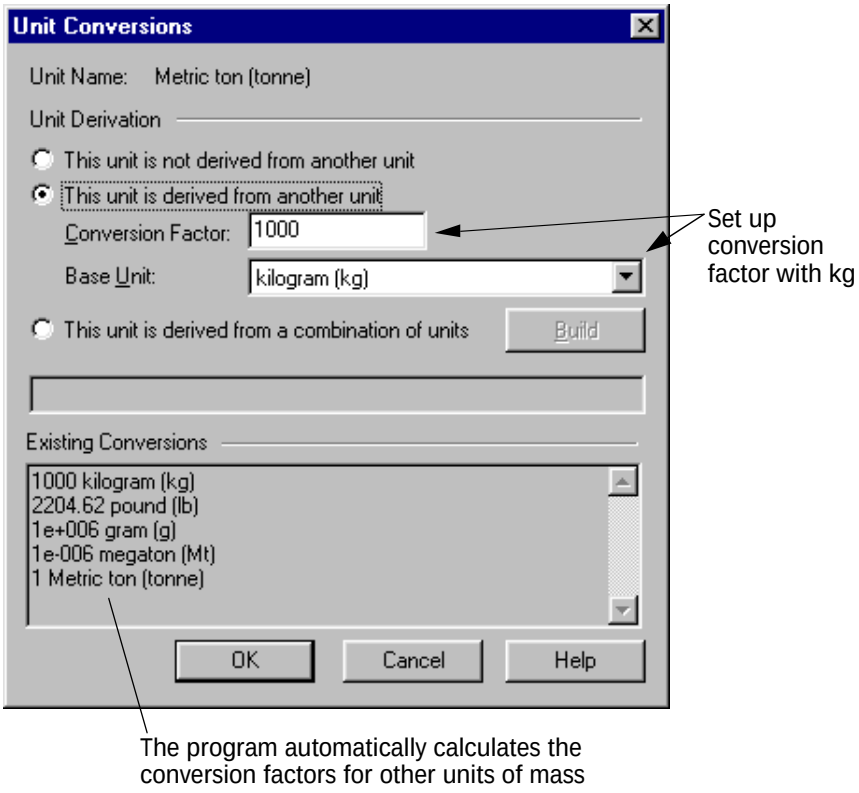
Unit Conversions
Unit Name: Metric ton (tonne)
Unit Derivation
This unit is not derived from another unit
This unit is derived from another unit
Conversion Factor: 1000
Base Unit: kilogram (kg)
This unit is derived from a combination of units
Build
Existing Conversions
1000 kilogram (kg)
2204.62 pound (lb)
1e+006 gram (g)
1e-006 megaton (Mt)
1 Metric ton (tonne)
OK
Cancel
Help
Set up conversion factor with kg
The program automatically calculates the conversion factors for other units of mass

Fig. 7.10 Setting unit conversion factors

It is possible to change unit *systems* in *CES Selector* (see Section 5.6.1). To achieve this it is necessary to define the equivalent units in each system. Do this as follows:

Click on the *Settings* button (under 'System Equivalents') in the *Unit Settings* dialog box (figure 7.9)

Click once on the unit system 'US Imperial' (figure 7.11), then select pound (lb) from the drop-down list box. Note that the program is able to calculate the conversion factors automatically.

Set the other equivalent units as shown in figure 7.11

Click on OK to finish.

Close the *Database Properties* dialog.

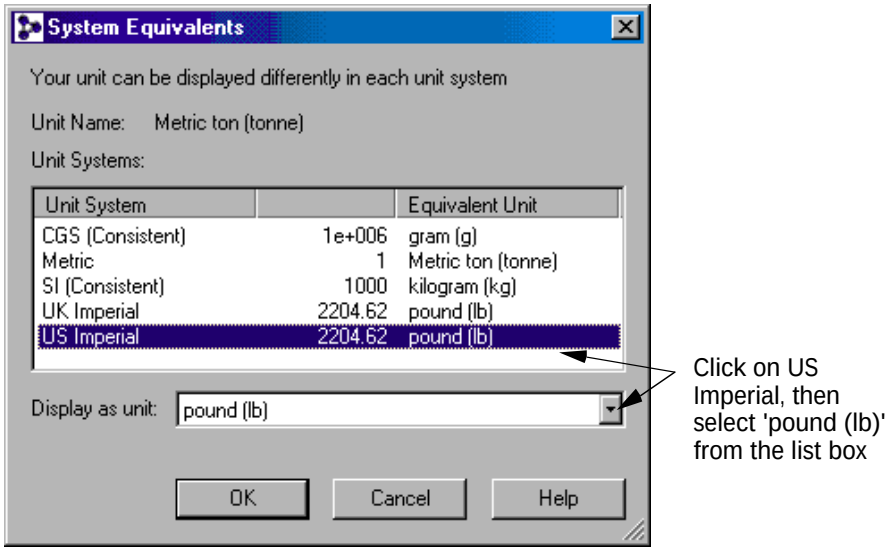
System Equivalents
Your unit can be displayed differently in each unit system
Unit Name: Metric ton (tonne)
Unit Systems:
Unit System
Equivalent Unit
CGS (Consistent) 1e+006 gram (g)
Metric 1 Metric ton (tonne)
SI (Consistent) 1000 kilogram (kg)
UK Imperial 2204.62 pound (lb)
US Imperial 2204.62 pound (lb)
Display as unit: pound (lb)
OK
Cancel
Help
Click on US Imperial, then select 'pound (lb)' from the list box

Fig. 7.11 Setting equivalent units in each unit system.

7.5 Creating a New Table

In this exercise you will create a new table containing information about material suppliers, then make links between this table and the materials table. You will also learn how to create a form to change the format of the information displayed in the *Attributes* window.

The Suppliers table will include the following attributes:

Text attributes	'Name', 'Address' and 'Telephone number'
Range attributes	'Batch size capability' (tonnes) and 'Lead time' (weeks)
Discrete attribute	'Quality of product' (High, Medium or Low)

Create a new table of suppliers, as follows:

Click on the *Database* tab in the *Control* window

Click on the *New Table* button

Create an empty table in the Create Table page of the *New Table* Wizard

Note that you can also base the new table on a standard template in the *New Table Wizard*. This does a lot of work for you, by automatically creating all the attributes, units, etc, for the new table, in the same form as the tables from Granta Design. It is essential to do this if you are creating a new Weblinks table.

Give the new table the name 'Suppliers' in the *New Table* Wizard

Link the new table to the *Materials* table, by checking the box in the Table Links page of the *New Table* Wizard, then *Finish* the Wizard.

A new table 'Suppliers' will appear in the list in the *Control* window. You will open this table later to add suppliers.

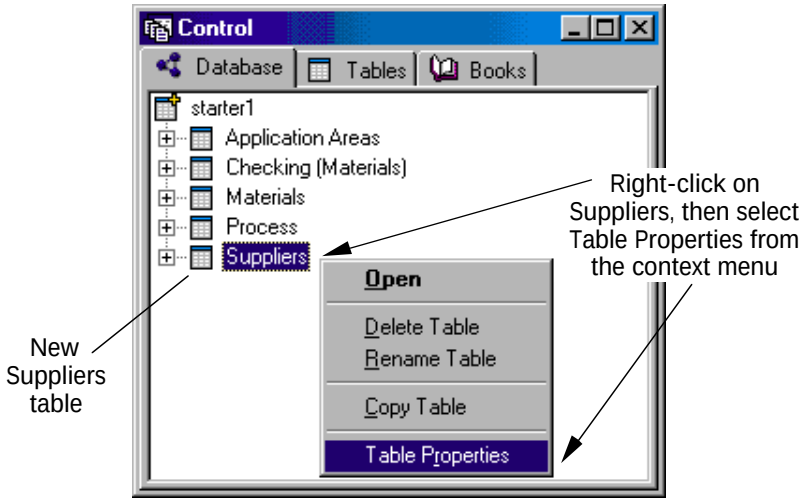

Fig. 7.12 The *Control* window showing the new Suppliers Table.

7.5.1 Defining the Structure of a Table

We now need to create the structure of the Suppliers table - ie define its fields. Do this as follows:

Click on the Database tab in the *Control* window

Either: Right-click on the Suppliers table entry on the Database tree, and select the 'Table Properties' option from the context menu (figure 7.12);

or: Left-click on the Suppliers table entry on the Database tree, and select the menu option *Database / Table Properties*.

Click on the Attributes Tab on the *Suppliers Properties* dialog box (figure 7.13)

We wish to add the following fields: Name (which will be of type 'short text'); Address (long text); Tel No (short text); Fax No (short text); Quality of material ('3-value' discrete); Typical batch size (range) in tonnes; Lead time (range) in weeks; Web address (hyperlink); and Last updated (date).

Click on *New* in the *Suppliers Properties* dialog to add a new field

Enter the name of the new field (eg 'Lead time') in the left column and select the data type (eg 'range') and units where applicable (eg 'weeks') from the list boxes near the bottom of the dialog box, as shown in figure 7.13.

For the Discrete property 'Quality of material', set the property type to *Discrete*. The units list will change to a list containing the available discrete properties. Select the Discrete Type '3-value' from the list box.

Add the remaining attributes as shown in figure 7.13.

Click on *Apply* when you have finished. The attributes will be arranged alphabetically.

Notes:

(i) The new discrete type '3-value' is available in the list of discretes as a result of the actions described in Section 7.4.1; and the new unit type 'tonne' is available in the units list, as a result of the actions described in Section 7.4.2.

(ii) To delete a row from the table, click once on the attribute name to highlight the row, then click on the *Delete* button or press the 'Del' key on your keyboard.

(iii) It is possible to include graphical information in database records using the 'picture' data type. (An example is the process schematic in each process record - see figure 5.12.) The attribute is set to 'picture' using the list box at the bottom of the *Table Properties/Attributes* dialog. The *Picture Gallery* is used to import pictures into the database (see section 7.5.5).

The relationships (links) between tables can be changed using the Related Tables tab on the *Table (Supplier) Properties* dialog.

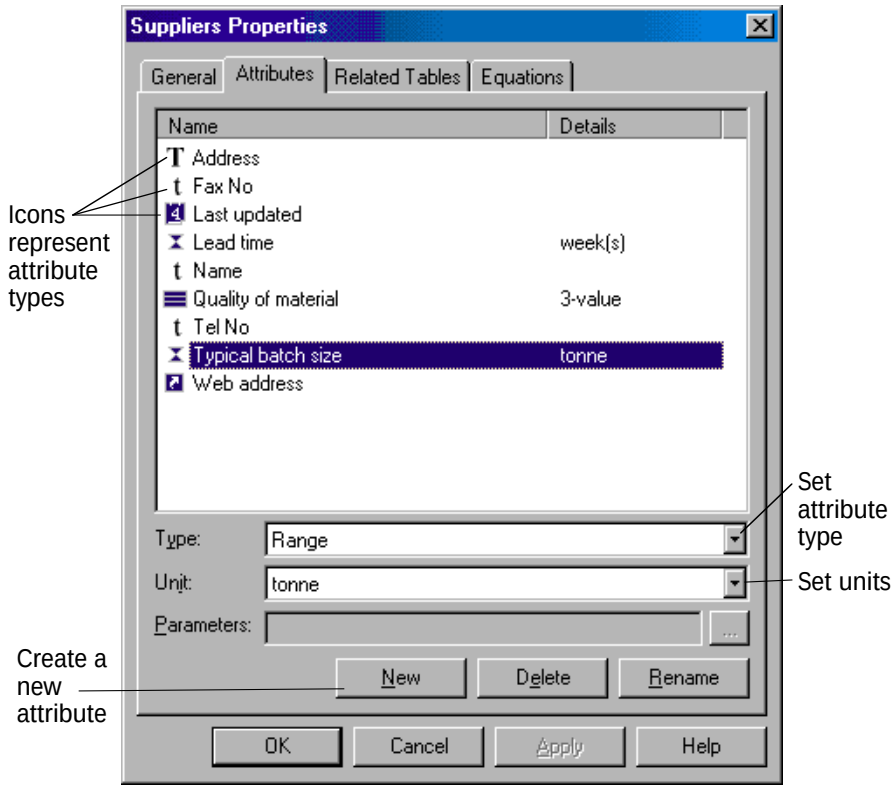

Fig. 7.13 Defining the structure of the Suppliers table.

Add records to the Suppliers table using the methods described in Section 7.3.2. Build the tree structure shown in figure 7.14.

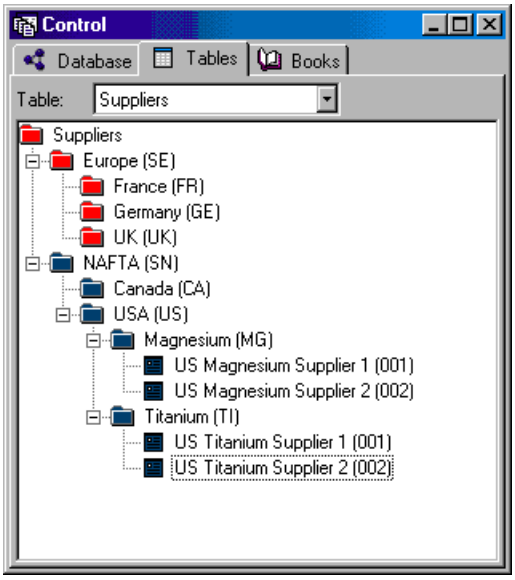

Fig. 7.14 Suppliers table tree

Now add some data to the record 'US Magnesium Supplier 1', as shown in figure 7.15.

To enter the 'Last Updated' date, click on the ... button, and select a date from the *Date Picker* dialog. Today's date will be highlighted.

To enter a Web Address, either:

(i) type a URL into the Web Address field

(ii) open your web browser at the relevant web page and copy the URL from the 'Address' field at the top of the browser to the clipboard and then paste it into the 'Web Address' field ; in the *Suppliers* table in *Constructor;*

(iii) drag the URL icon from the 'Address' field at the top of your web browser into the 'Web Address' field in the *Suppliers* table in *Constructor*. (You will need to arrange the windows so that you can see both your browser and the *Attributes* window in *Constructor* at the same time.)

You can open the URL automatically by clicking on the ... button in the 'Web Address' field, and clicking on the Launch button in the *Web Address* dialog.

Note that the attributes are organised alphabetically according to their type - ie all range attributes are listed together, all short text is stored together, etc. This is the style of the form called '<All Alphabetical>' which is the default form when a table is first created.

7.5.2 Converting Between Numerical Data Types

It is possible to convert some data types into others, in the *Table Properties* dialog. *Constructor* may prompt you for some user-input, depending on the conversion. For example, to convert the 'Typical batch size' attribute from a Range to a Point variable:

Open the *Supplier Properties* dialog, as shown in figure 7.13
(Open the *Suppliers* table on the *Table* tab in the *Control* window, then select Database\Table Properties)

Click on the *Typical batch size* property

Then change the *Type* (near the bottom of the dialog) from Range to Point.

Click on 'Yes' to Continue, then select the method of conversion: Geometric Mean or Arithmetic Mean.

If you choose the Arithmetic mean, the Point value will be the arithmetic average of the minimum and maximum of the range, ie

$\text{Point} = (\text{Range}_{min} + \text{Range}_{max})/2,$ eg $(0.05 + 2)/2 = 1.025$

If you choose the Geometric mean, the Point value will be the geometric mean, ie

$\text{Point} = \sqrt{(\text{Range}_{min} \times \text{Range}_{max})}.$ eg $\sqrt{(0.05 \times 2)} = 0.316$

Conversions that are allowed are shown in the following table:

Convert From:	To:
Long Text, Short Text	Hyperlink
Long Text, Short Text	Date
Point	Range, Integer
Range	Point, Integer†
Integer	Point, Range

Table 7.1 Allowable conversions between data types.
† Conversion can use an arithmetic or geometric average.

For all other conversions , (eg from Range to Text) the data will be lost. (See Section 3.3 for further information on attribute types.)

7.5.3 Creating a Form

The format of the information about the supplier shown in figure 7.15 could be improved. This can be achieved by creating a 'form' which specifies the order in which the fields are displayed and the format of headings. We will create a form for the Suppliers database called 'Standard'. Proceed as follows:

Open the *Database* tab on the *Control* window

Open the *Suppliers* branch of the tree

Open the *Forms* sub-branch of Suppliers

Right-click on *Forms*, and select the *New Form* option from the context menu.

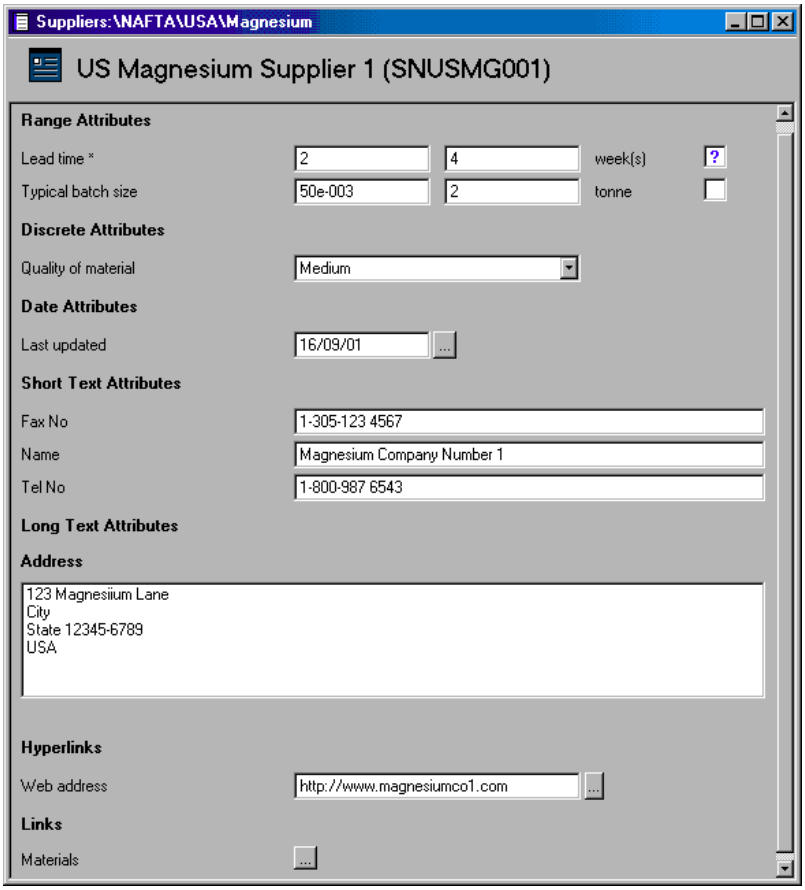

Fig. 7.15 A record in the Suppliers table using the *default* form (<All Alphabetical>).

Figure 7.16 shows the *Edit New Form* dialog. Create the headings 'Contact Details' and 'Product Information' and position the attributes under these headings as follows:

Click on the *New* button to create a new heading, then change the heading name in the left window pane to 'Contact Details'

Transfer the attributes 'Name', 'Address', 'Tel No', 'Fax No', 'Web Address' and 'Last Updated' from the right window pane to the left, using the *<-Add* button. (Use *Remove* -> to do the reverse.)

Note that you can change the order of attributes in the left window pane using the *Move Up* and *Move Down* buttons.

Add the 'Product Information' heading, and transfer the remaining attributes under it.

Click on *OK* to exit the dialog box.

Rename 'New Form' to 'Standard' on the *Database* tab of the *Control* window

Having created the new properties form, we wish to view the record. It is first necessary to set the new form ('Standard') to be the *current* form - ie the form currently in force in the *Constructor* session. (You can have as many forms as you like, displaying some or all of the attributes in different formats.) We will also set this form to be the 'Default' - ie the form which is used for the *Suppliers* table when the database is opened in *Selector*.

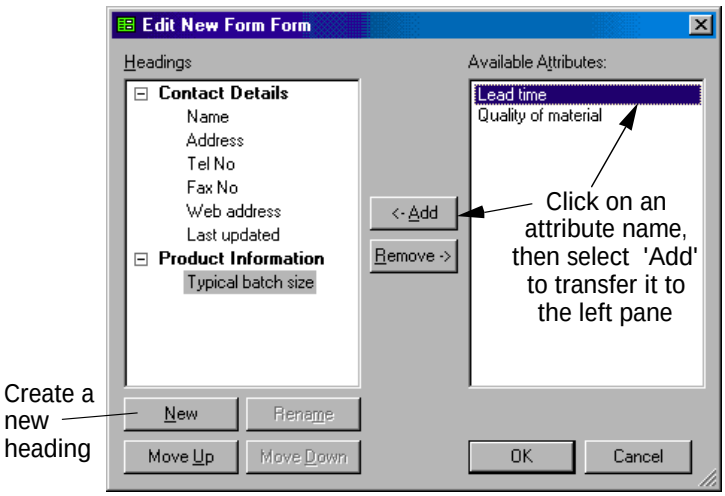

Fig. 7.16 Creating a new form for the Suppliers table

Right-click on the 'Standard' form icon on the Suppliers branch in the *control* window. Select the option 'Set Current' (figure 7.17)

Note that 'Standard' is now shown in bold face to indicate that it is the current form.

Right-click on the 'Standard' form icon again and select the option 'Set Default'

This time a small red tick mark appears on the form icon, indicating that it is the default form. View the new form, and then create some links...

Return to the record 'US Magnesium Supplier 1'. It should now be displayed with the improved format.

Scroll to the bottom of the record and click on the *Materials* link button.

Use the methods described in Section 7.3.3 to add a link to all Magnesium Alloys. (Simply check the box next to Magnesium in the *Linked Records* window.)

Finally, open the record for 'Magnesium alloy EQ21' (created in Section 7.3.2), and check its supplier links. It should be linked to 'US Magnesium Supplier 1'.

7.5.4 Filters

Filters provide a facility for defining which records are viewed in *Selector* (see Section 3.2.6). A new filter can be created on the *Database* tab of the *Control* window in a very similar way to a new form (eg see Section 7.5.3). Once a new filter has been

created, its name will appear automatically in the *New Folder* and *New Record* Wizards (see Section 7.3). So new records can be added to the new filter easily (see Section 7.3.2).

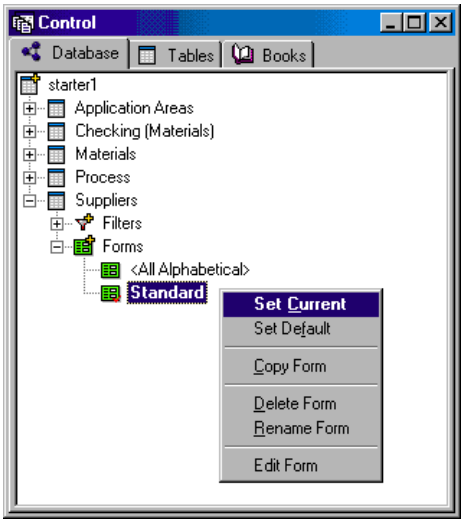

Fig. 7.17 Setting the current form

An existing record can be added to a filter as follows:

(i) Right-click on a record name on a table tree (eg Magnesium EQ21 on the Materials tree), and select 'Record Properties' from the context menu. Then click on the 'Filters' tab in the dialog box, and select the filters for the record.

(ii) When setting the filters for a folder record (using the procedure in (i)), there is an additional option: 'Add all children of this record to the selected filter'. Check this box if you would like all records below this folder to be included in the filter. For example, a class-specific filter, like 'light alloys' might include *all* materials on the tree below the Magnesiums folder.

(iii) To add/remove a record from the *current* filter, right-click on the record name on the table tree and select /de-select 'In Current Filter' on the context menu.

7.5.5 Picture Gallery

Importing a picture into a data record utilises the *Picture Gallery*.

Select the *Process* table from the drop-down list on the Tables tab of the *Control* window

Open a record on the *Process* table tree, for example: Process\Casting\Ceramic Mould Casting

Scroll through the record until you see the attribute 'Process Schematic'.

Click once on the ... button.

This will open the Picture Gallery as shown in Fig. 7.18.

Select the name of a picture in the left window pane. A preview of this picture will appear in the middle of the *Picture Gallery* dialog box.

Click on *OK* to insert this picture into the Process data record.

Notes:

(i) For the pictures to be available in the picture gallery, they must first be imported from an external file. Do this using the **Import** button in the *Picture Gallery* dialog box. Alternatively use the **Paste** button to paste a picture from the Clipboard into the Gallery. The picture must be in one of the following file formats: Bitmap *.bmp; Enhanced metafile *.emf; Windows metafile *.wmf (See Appendix C1).

(ii) Pictures in the gallery can be classified into 'groups' to simplify their management. Click on the **Groups** button to do this. (See further details in the on–line *Help* tutorials.

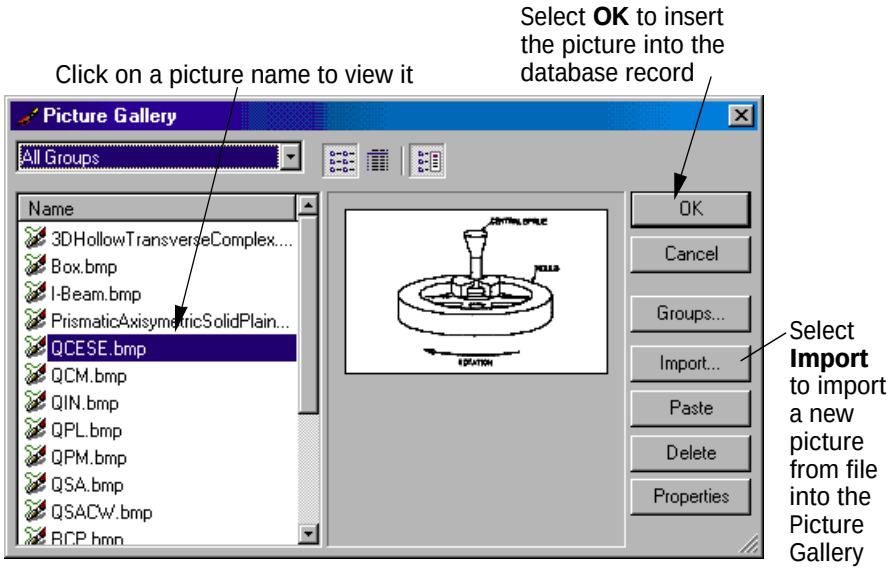

Fig. 7.18 The *Picture Gallery* dialog box.

7.6 Conclusions

This chapter has shown you how to use some of the key components in *CES Constructor*. There are many other facilities. Once you have made a start, we hope you will find most of these to be intuitive. They are easily learned by working through the Tutorials in the on-line *Help* system.

A few aspects of the workings of *Constructor* are a little more complex, and these are described in the next chapter.

Chapter 8 Advanced Construction Features

This Chapter presents information about some of the advanced features of *CES Constructor*. These include some technical details about links, information about setting up automatic data checking, details of units and currency conversions, and instructions about how to import data into *Constructor*.

8.1 Links

Links allow relationships between records in different tables to be defined. Among other things, this means that selection can take place across tables.

For records to be linked, the tables that contain the records must be *related*. This is a property of the tables. The relation is valid in both directions i.e. if the *Materials* table is related (linked) to the *Suppliers* table, then the *Suppliers* table is also related (linked) to the *Materials* table (see figure 8.1). An illustration might be that a particular aluminium alloy is available from ALCOA; and the reverse: ALCOA can supply the particular aluminium Alloy.

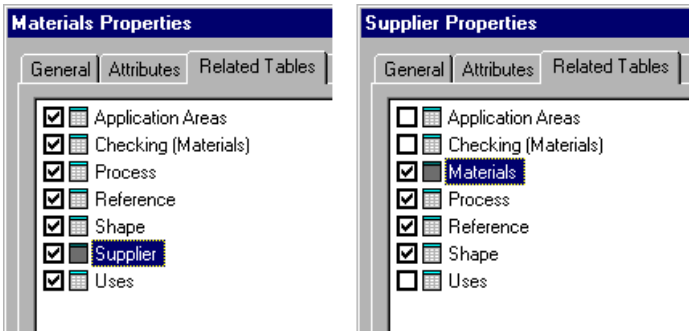

Fig. 8.1 Part of the *Table Properties* dialog showing two related tables

When a link is created between two records in *Constructor*, three things happen:

(i) The new link is shown in bold. This is know as a *direct* link, and is illustrated in figure 8.2: 'Cast aluminium alloys' (a record in the Materials table) can be supplied by 'ALCOA' (a record in the Supplier table).

(ii) If either of the linked records are folders, then any records below the linked records in the trees (the *child* records) are also linked together with *indirect* links, as shown in figure 8.3. The various classes of cast alloys are *all* linked to ALCOA.

This is a consequence of the hierarchical structure of the tables... Since a folder represents the collection of the records below it in the tree, if a link is made at the level of a folder, then all the children of that folder are also linked. In the example above, this is like saying 'ALCOA can supply *all* Cast Aluminium Alloys'.

This hierarchical inheritance of links can be avoided by making links directly from *record to record*, and not from *folder to folder*.

(iii) The parents of the linked records are also linked together as shown in figure 8.4. This is again a function of the hierarchical structure of the database. In this example, it is like saying that 'at least one supplier in the USA (ALCOA) can supply at least one aluminium alloy (all cast aluminium alloys), and by implication at least one light alloy and by implication again, at least one metal'.

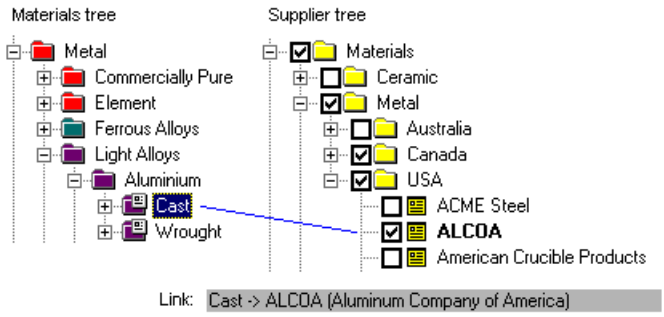

Fig. 8.2 A direct link between the 'Cast aluminium alloys' folder and the 'ALCOA' record.

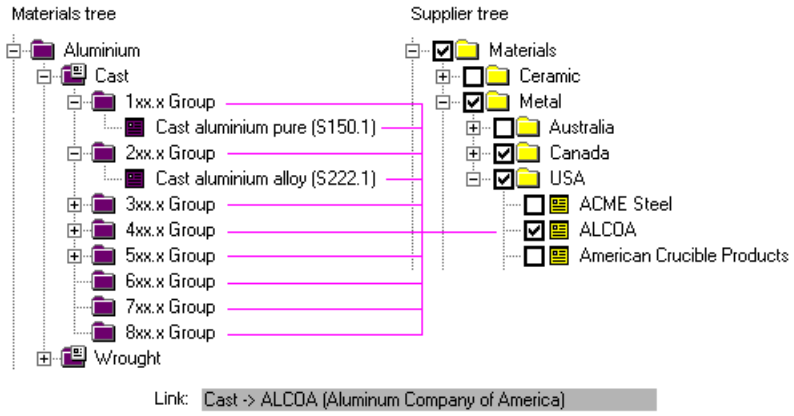

Fig. 8.3 Indirect links between child records of Cast aluminium alloys and ALCOA, generated by the direct link shown in figure 8.2.

CES Selector uses this information when making a selection based on links. An example selection might be that a material is only suitable for a given design if, as well as satisfying all of the constraints on its attributes (strength, stiffness, etc.), it is also available from a supplier in the USA. All cast aluminium alloys pass this selection, as they are available from ALCOA, which is in the USA folder in the *Supplier* table.

The originating direct link of any indirect link can be found by highlighting the indirect link in *Constructor*. The originating link is shown in the status bar of the *Linked Records* window, as shown in figure 8.5.

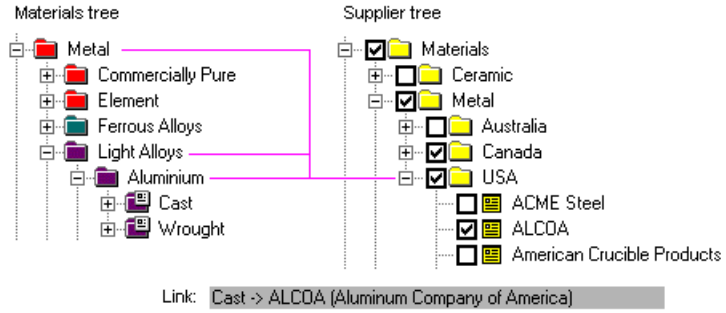

Fig. 8.4 Indirect links between parent records of 'Cast aluminium alloys' and parent records of 'ALCOA', as a consequence of the direct link shown in figure 8.2.

Fig. 8.5 The Linked Records window showing links for the record 'Metal' in the material table. Highlighting the indirect link to ALCOA shows that the originating direct link was from 'Cast Aluminium Alloys'.

8.2 Automatic Data Checking: Implementation Details

The principles behind the automatic data checking in *Constructor* are described in Section 6.10. This section describes some of the implementation details.

8.2.1 The Way Checking is Structured

In *CES* 3.2, data for checking is kept in a separate data table which is independent of the data being checked. A database can contain any number of checking tables, although any particular table can only have one checking table. Any table can be used by one or more other tables in the database as their checking table.

For example, there might be a data table of 'Commercially Available Materials' and a table of 'Research Materials'. These could both share a single 'Checking Materials' table, but neither could use another checking table as well.

The assignment of a checking table is one of the properties of a table. It is enabled in the *Table Properties* dialog box as shown in figure 8.6.

Once a checking table has been assigned, a record is automatically matched to its checking record by tree name. The record is matched down the checking tree as far as possible. In the example shown in figure 8.7, 'Cast Magnesium Alloy AM60' is checked against the checking record for all 'Cast Magnesium Alloys'.

So it is necessary to use the same tree structure and names in the checking table as for the table(s) being checked.

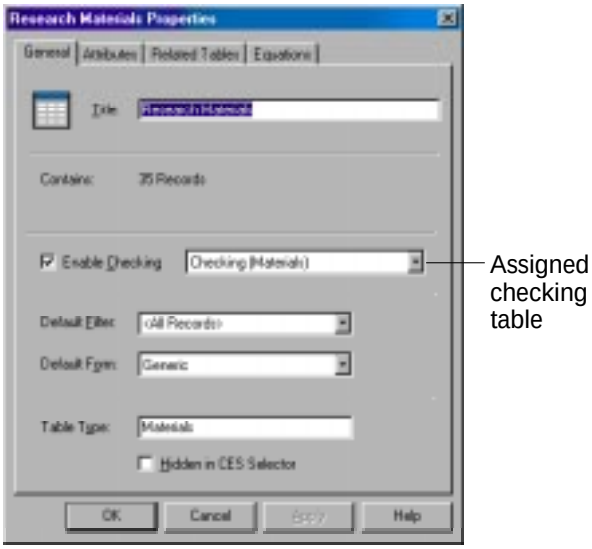

Fig. 8.6 Assigning a checking table in the *Table Properties* dialog

For range checks, each attribute is matched to its checking attribute by name i.e. the attribute Young's Modulus in the Materials table, will be checked against the attribute named Young's Modulus in its checking table. If an attribute's name does not exist in the checking table, it will not be checked.

The correlation checks consist of 'equations' that are assigned to the checking table. The equations are a combination of attributes in the table, and constants from the 'constants' table where needed.

An equation is one of the properties of a table. It is set in the *Table Properties* dialog box as shown in figure 8.8.

In *CES Constructor* 3.2 only numeric attributes: range, point and integer, can be checked.

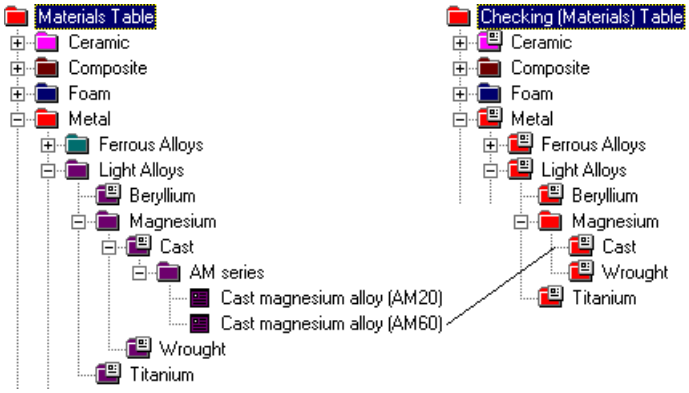

Fig. 8.7 The checking record for 'Cast Magnesium alloy (AM60)' is 'Cast Magnesium'.

8.2.2 How the Checks are Calculated

For numeric *point* attributes, if the value falls within the checking range, then the attribute passes. For numeric *range* attributes, the geometric mean is calculated from the maximum and minimum values. If the geometric mean falls within the checking range, then the attributes 'passes'.

A statistical method is used to calculate the checking range of equations from the checking range of their constituent attributes. In the *CES* materials table the correlation equations are chosen to be dimensionless (which means they work irrespective of the units system chosen), but this does not have to be so.

An attribute that is set as 'Not Applicable' will only pass if the attribute is also set as 'Not Applicable' in the checking table for that record.

By convention, checking tables are hidden, so that they do not appear in *Selector* – the range of the values for the attributes in a record in a typical checking table is often 10 times greater than those of the checked table, and are not useful for selection purposes.

8.3 Constants and Parameters

8.3.1 Constants

CES Constructor contains a table in which to store common universal constants. These constants can be used in *Selector* as part of a user–defined property when plotting a selection chart, or they can be used in *Constructor* as part of a checking correlation equation or functional data expression.

A constant is one of the properties of the database. It is set in the *Table Properties* dialog as shown in figure 8.9.

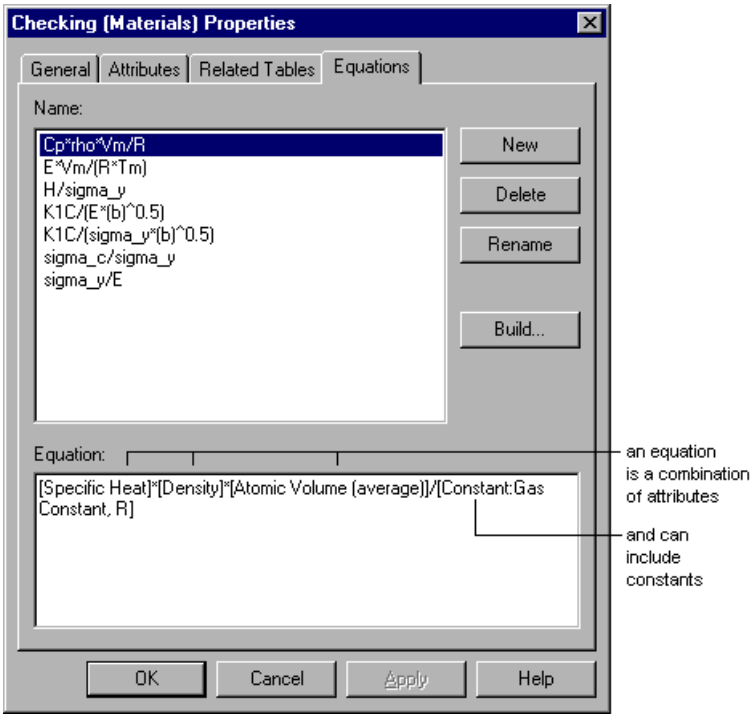

Fig. 8.8 Equations in the *Table Properties* dialog box.

Fig. 8.9 Constants in the *Database Properties* dialog

8.3.2 Parameters

Parameters are the independent variables used in functional data. For example, you could store the variation of Young's Modulus E with Temperature T for a material as pairs of measured (T, E) values. If T was defined as a *Parameter*, then you could perform a selection based on the Young's Modulus E at a specified value of Temperature T. *Selector* would interpolate between temperatures to find the value of E at the user-specified value of T.

A parameter is one of the properties of the database. It is set in the *Database Properties* dialog as shown in figure 8.10. Each parameter has specified units and a default value, (the default value can easily be over-ridden by *Selector* users). The 'Scale' option in the dialog box 'Lin' or 'Log' (figure 8.10) enables you to specify whether the interpolation done by *Selector* is done on linear or logarithmic scales. If a parameter varies over many orders of magnitude, so that graph of the property is often be plotted with a logarithmic scale for that parameter (eg a fatigue 'S-N' curve is often against log(N)), then it may be more accurate to do the interpolation by assuming a logarithmic variation of the parameter.

Fig. 8.10 Parameters in the *Database Properties* dialog.

8.4 Units and Currency

The attributes in the database can be stored in any units, but usually when those attributes are displayed in a *form*, it is desirable to display them in a consistent system of units. Examples of consistent *unit systems* in common use are the US Imperial, UK Imperial (fps), Systeme Internationale (SI), Metric, Absolute Practical System (mks) and cgs. *CES* provides sophisticated facilities for performing the conversions.

8.4.1 Storing and Viewing Data

Attribute values are stored in the database *independently* of the unit assigned to the attribute in the *Table Properties* dialog. If you alter a unit assigned to an attribute, the value of the property remains the same. For example, if you assigned the unit 'metre' to the attribute 'Length' and entered the value '256' in a record, then the value of 'Length' in that record would be '256 metre'. If you subsequently changed the unit of the Length field to say 'centimetre', the value in 'Length' would remain as '256', so it would become '256 centimetre' in that record.

Whatever units are chosen for setting the data values in the database using *Constructor*, it is still possible to view attribute data in another unit if you have set up *equivalent* units for other unit systems. For example if the 'yard' has been set up as an equivalent unit to the 'metre', then the value of the attribute can be displayed in either unit in *Selector* (256 metre or 280.1 yard), but it will remain stored as '256 metre' in the database. It is also possible to display the data in a different unit in *Constructor* if you alter the *Preferred* units system (see Section 8.4.6).

8.4.2 Unit Name and Symbol

When a new unit is created, it is given both a *Name* and a *Symbol*. The symbol is what you will see most of the time in both *Selector* and *Constructor*, but the name is shown wherever clarity is required. Example: Name: metre, Symbol: m (figure 8.11)

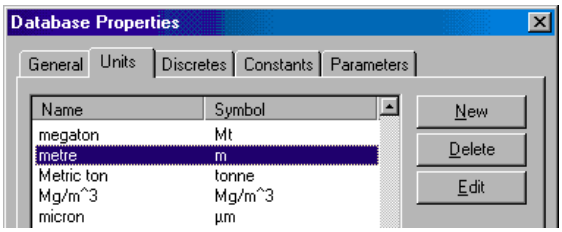

Fig. 8.11 Part of the *Database Properties* dialog showing the unit 'metre'

8.4.3 Unit Systems and Equivalent Units

If a new unit is common across all unit systems (Example: volt (V)), then there is no need to specify any system equivalents.

Many units, however, belong to some unit systems, but not others. For this reason, it is possible to specify *equivalent* units in *Constructor*.

Consider some arbitrary attribute 'Length', that is stored in the database in foot (ft). Assume the chosen unit system for the database is 'Metric', which does not contain 'ft'. It is necessary to tell *CES* that when it encounters an attribute stored in 'ft' it should use some equivalent unit in the Metric system (eg metre (m)), and what the relative size of these two units is.

So, assuming that metre (m) is already stored in the database, all that is needed is to set the relative *conversion factor* from the foot to the metre:

foot (ft) = 0.3048 x metre (m)

The procedure is shown in figure 8.12.

The equivalence, which is shown in figure 8.13, can represented linguistically as follows:

"When using the 'Metric' unit system, display attributes that are stored in units of 'ft' using units of 'metre' instead."

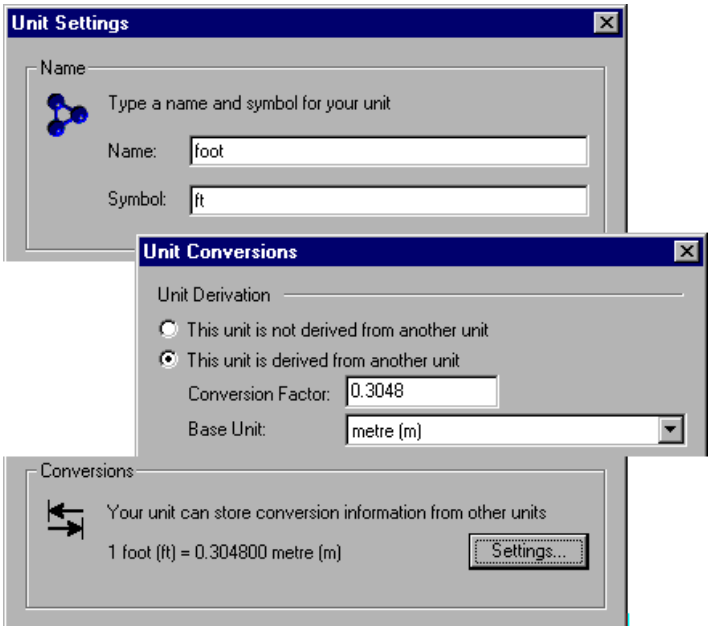

Fig. 8.12 Part of the *Unit Settings* and *Unit Conversions* dialog for the unit 'foot'

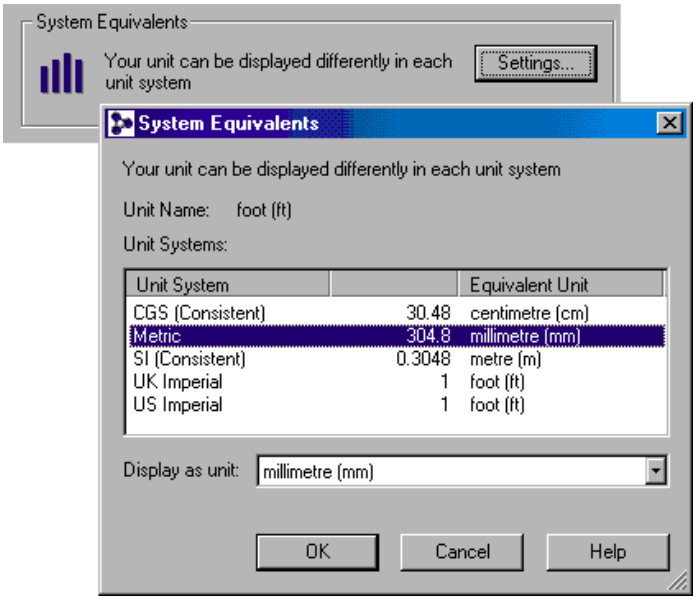

Fig. 8.13 Part of the *Unit Settings* and *System Equivalents* dialog for the unit 'foot'

The recommended approach to creating sets of equivalent units is:

(i) create all of the individual units;

(ii) set the conversion factors between units;

(iii) create unit systems and then set equivalent units.

8.4.4 Combined Units

Many attributes have units that are combinations of simpler units. For example, Torque is often expressed in N.m in the Metric unit system, Fracture Toughness in $MPa.m^{1/2}$. *Constructor* allows these *combined* units to be created from a combination of other units already stored in the database. The principal advantage of this is that *Selector* and *Constructor* know how big each of the constituent units are relative to their equivalent units in the database. The programs can therefore automatically calculate the conversion factors for any other combined units of the same dimensions.

For example, consider the Metric unit of pressure, the Pascal (Pa): 1 Pa = 1 N / $1m^2$ (figure 8.14). If the database already contains 'N' and 'm', and knows that the 'N' is equivalent to 0.225lbf and the 'm' equivalent to 39.37in, in the Imperial unit system, then when the 'Pa' is created as a combination of the 'N' and the 'm', the program knows that an equivalent unit to the Pa is the lbf/in^2, and more than that, that there are 0.000145 of them.

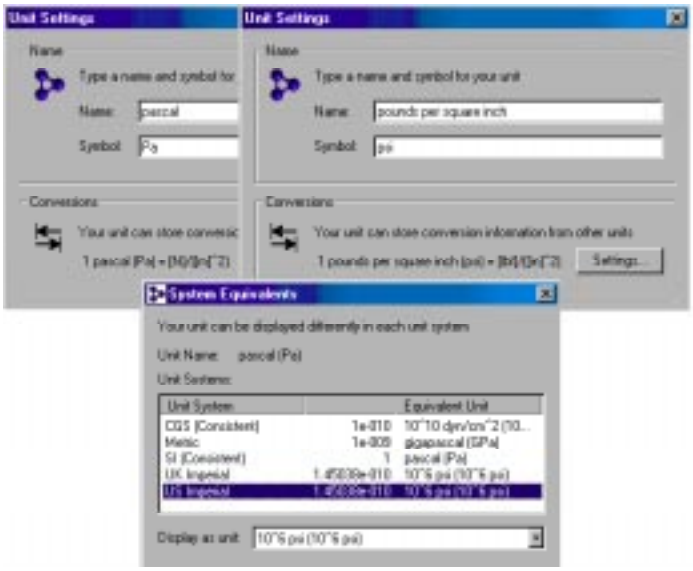

Fig. 8.14 Part of the *Unit Settings* dialog for the combined units 'pascal' and 'pound force per square inch' and the *System Equivalents* dialog for the unit 'pascal' showing the relationship between the two.

8.4.5 Currency

All currency data stored in the database is stored in the *Default Currency* which is set in the *Database Properties* dialog (figure 8.15). If you alter the *Default Currency* setting, the data value stored in the database will remain the same. For example, you set the Default Currency to 'US Dollar (USD)', and enter the value '5' for the attribute 'Flat Fee' which has units of 'currency'. The value of 'Flat Fee' in that record would be '5 US Dollars'. If you subsequently change the *Default Currency setting* to 'Australian Dollar (AUD)', the stored value in 'Flat Fee' remains as '5', it is now '5 Australian Dollars'.

The currency unit can be a component of a combined unit as shown in figure 8.16.

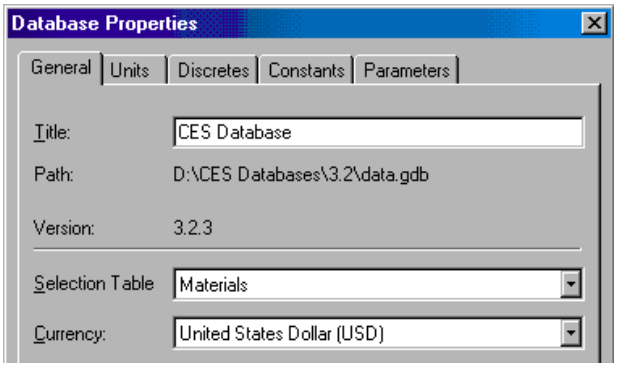

Fig. 8.15 Part of the *Database Properties* dialog showing the default Currency.

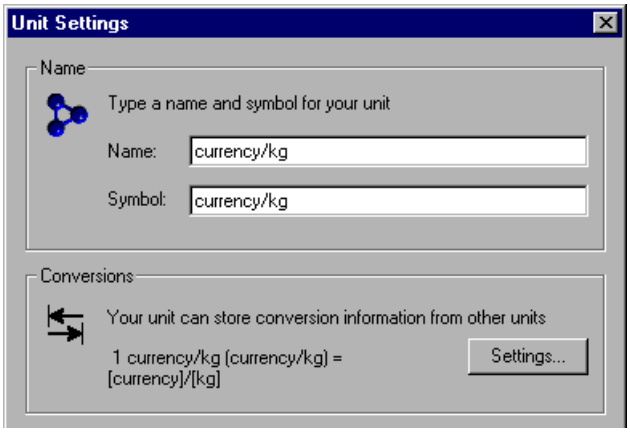

Fig. 8.16 Part of the *Unit Settings* dialog for a combined unit that uses the currency unit

Whatever the *Default Currency* used in the database, it is possible to view the data values in another currency if conversion data exists for that currency. The data value is converted for display to the currency that is set as the *Preferred Currency*. For example, consider an attribute 'Flat Fee' with units of 'currency'. The Default Currency stored in the database is 'US Dollars'. A record contains the data value of '5' i.e. '5 US Dollars'. If the *Preferred Currency* is set to 'Australian Dollar (AUD)' *Constructor* uses the information in the currency conversion file to calculate a conversion factor. For viewing purposes, the value becomes '7.9 Australian Dollars', but it will remain stored as '5 US Dollars' in the database.

8.4.6 Preferred Currency and Unit System

For the currently open database in *Constructor*:

Preferred Currency is the currency unit in which currency data is currently displayed.

Preferred Unit System is the unit system in which attribute data is currently displayed.

These are set in the *Options* dialog as shown in figure 8.17.

Fig. 8.17 Part of the *Options* dialog showing preferred currency and units viewing settings

Changing the *Preferred* settings does not affect the way that the numbers are stored in the database, only the way they are displayed.

As well as enabling attribute data to be viewed in different units to those in which they are stored, the *Preferred Database Options* settings allow data to be entered as values in the *preferred* setting, even though they are stored in the *default* setting. For example,

consider the attribute 'length' which is stored in the database with units of 'm'. Suppose you obtained data for further records, but the attribute data values were in 'ft'. Changing the *Preferred Unit* System to a system which used 'ft' eg 'US Imperial', would allow you to enter the data in 'ft'. However the data values would be stored in 'm' in the database. The advantage of the *Preferred Units and Currency* options is that they allow the user to view or enter data from various sources in different units, but store data in one consistent unit set.

When a new database is created, the *Preferred* settings are used to create a currency unit and unit system in the new database. See below for details. The *Preferred* settings can be changed in the Options / General dialog (see figure 8.17).

Various options for the preferred currency and unit systems for the current database and for new databases are provided in Appendix C4.

8.4.7 Editing Exchange Rates

Currencies and their conversion factors are located in a file called 'currency.csv' in the *CES* installation directory. (This file must contain the *Default* currency used by the database.) Up-to-date copies of currency.csv can be downloaded from the Granta Design web site. It is not possible to edit currency conversion factors from within *Constructor*, however, it is possible to edit the currency.csv file as follows:

(i) Close all databases in *Constructor*.

(ii) *Make a backup of currency.csv* (in the *CES* installation directory)

(iii) Open currency.csv using Microsoft Excel. *Do not use a text editor.*

(iv) Add a new currency or edit the exchange rates.

(v) Close the file and re-open your database in *Constructor*. The currency changes will be implemented automatically.

8.5 Creating Functional Attributes

8.5.1 Adding a parameter to the database

The following section provides a simple example of creating a functional data attribute dependent on one parameter. Functional data can be of type 'Array' or 'Expression'. An array contains a set of (measured) data points, whereas an expression contains a mathematical equation. The attribute created in this example is an 'Expression'.

Details of the syntax of functional attributes can be found in Appendix D.

Before an attribute is created, any parameters to be associated with it must exist. *Parameters* are properties of the database. This allows them to be associated with attributes in any table.

Open the database database 'starter5.gdb' in *Constructor*

Select the *Database Properties* command from the *Database* menu.

Click once on the *Parameters* tab to view the Parameters page (figure 8.18)

Click on the *New* button to create a new parameter

Name the parameter B1

Ensure that the parameter B1 is selected

Enter the Default Value of 10 for the parameter

Do not assign any Units to the parameter, leave it set to '<None>'

Leave the Scale set to 'Log'

Click OK to exit the Database Properties dialog.

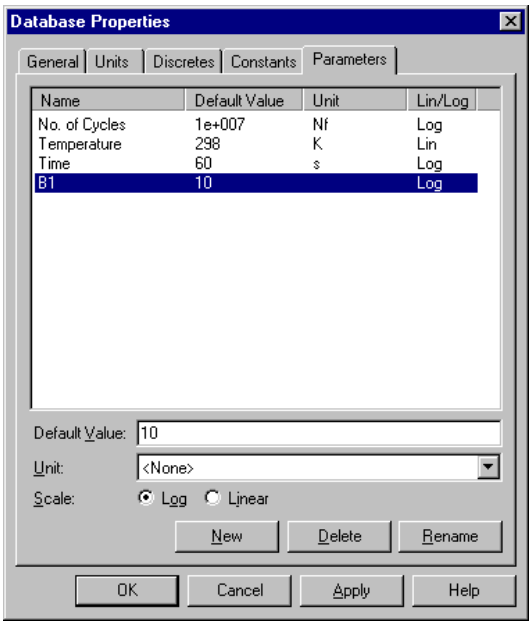

Fig. 8.18 Adding a parameter to the database.

8.5.2 Adding a Functional Attribute

Now create two new attributes:

View the Materials table tree in the *Control* window.

Open the *Table Properties* dialog for the Materials table.

View the *Attributes* page of the *Table Properties* dialog.

Create a new attribute and name it 'R1'.

Set the attribute Type of R1 to 'Range' and let the Unit be 'None'.

Create a new attribute and name it 'F1' (Fig. 8.19)

Set the attribute Type of 'F1' to 'Functional Range' and let the Unit be 'None'.

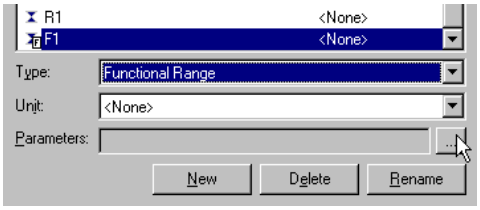

Fig. 8.19 Creating new attributes for the functional data.

Assign the parameter 'B1' to functional attribute 'F1' as follows:

Select 'F1' and click on the Browse '...' button for Parameters.

In the *Attribute Parameters* dialog, check the box for the parameter 'B1' (Fig. 8.20) and click OK.

This closes the *Attribute Parameters* dialog and returns to the *Table Properties* dialog. The Functional Range attribute 'F1' now has the parameter 'B1' assigned to it. (This should be shown in the Parameters: box at the bottom of the *Table Properties* dialog.)

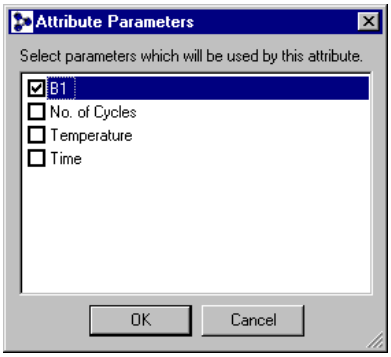

Fig. 8.20 Assigning parameter 'B1' to functional attribute 'F1'

Click on OK to exit the Table Properties dialog.

This has added the functional attribute 'F1' to the Materials table.

Set the Form for the Materials table to <All Alphabetical>

Open record 'Materials:\Metal\Ferrous Alloys\Carbon Steel\Low Carbon Steel'

There should be a new empty attribute 'F1'. Look under the heading 'Functional Range Data' (The **Functional Graph** button for the attribute is disabled, as it does not contain any data.)

8.5.3 Adding Data to a Functional Attribute

In the record 'Materials:\Metal\Ferrous Alloys\Carbon Steel\Low Carbon Steel'

Under the form heading 'Range Attributes', enter the following values for the attribute 'R1': Minimum 56, Maximum 89 (Fig. 8.21)

Fig. 8.21 Setting a value for property R1

Scroll to the form heading 'Functional Range Data'.

For the attribute 'F1', click on the Function Builder button

This opens the *Functional Data Expression Builder* dialog. The upper pane is where the function for the functional attribute is built. The lower pane lists those attributes, constants and parameters that can be used in a numerical expression.

Click on the 'New' button (Fig. 8.22)

A drop down list appears, enabling the user to choose the type of expression to be created.

Click on 'Expression'.

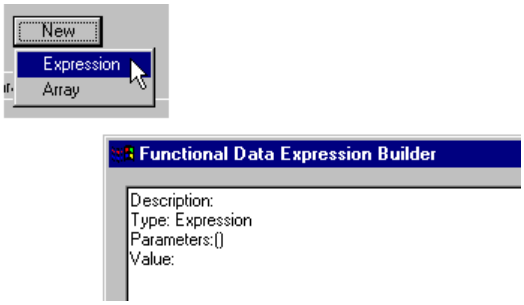

Fig. 8.22 Creating a new Expression

The 'skeleton' for a function of type 'Expression' appears in the upper pane, and the Constants/Parameters page of the dialog becomes visible, listing the Parameters in the database. The cursor is positioned to input a descriptive text string for the expression.

Type Domain 1 for the Description.

Now set the line for Parameters will to: 'Parameters: ([Parameter:B1]=1:10)' as follows:

Ensure that Parameters are shown in the lower pane.

Place the cursor between the brackets on the Parameters line.

Click on the Parameter Name 'B1' to select it.

Click on the Insert button to add the parameter to the expression.

Type =1:10 directly after the parameter name.

This states that the following function Value is valid for values of the parameter 'B1' between 1 and 10.

Now set the line for the Value to: 'Value: [Parameter: B1]^2*[R1]'

Position the cursor after 'Value:'

Select the Parameter Name 'B1' and click Insert.

Click the power ^ button.

Type the number '2'.

Click the multiplication × button.

Click on the Attributes tab and select the Attribute named 'R1' , then click on the Insert button.

The completed expression should look like figure 8.23. In mathematical notation, this expression means:

$F1 = B1^2 \times R1$, evaluated over the domain $1 < B1 < 10$.

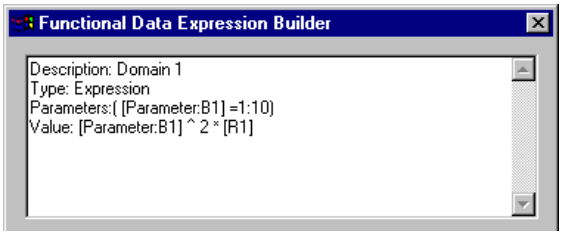

Fig. 8.23 The completed expression.

Click on OK to validate the function

The *Functional Data Expression Builder* dialog closes and the user is returned to the open record, containing the functional data that has just been input.

Click on to view a graph of the function.

Try plotting it on both linear and logarithmic scales (see Appendix D, Fig. D2).

For more information about functional data, See Appendix D, and information in the on-line Help.

8.6 Importing Data

CES Constructor has the ability to 'import' tables from other databases. This section discusses the data sources, restrictions on importing, and the importing process.

8.6.1 Data sources

Importing is currently supported for the following database formats:

- Granta Database (*.gdb)
- Microsoft Access 97 Database (*.mdb)
- DBase III, IV and V Database (*.dbf)
- Microsoft Excel Spreadsheet (*.xls)
- Text File (Comma separated and tab delimited formats) (*.txt, *.csv, *.tab)

If your existing database format is not supported, you may still be able to import data by first exporting from your existing database to a text format, (eg tab delimited) and then importing the resulting file into *CES Constructor*.

8.6.2 Restrictions

There are a some restrictions on importing data from external files, using *CES Constructor* 3.2:

(i) Data can only be imported into a new table - *not* into an existing table.

(ii) It is not possible to import *link* information from any database.

(iii) *Pictures* can be imported from Granta databases, but not from any other kind of database. For other databases, it is necessary to use the *Picture Gallery* to import each picture separately from a file (see Section 7.5.5).

8.6.3 Importing Procedure

(i) Before importing, it is recommended that you take backups of both the 'source' and 'target' (*CES*) files.

(ii) It is useful to 'prepare' the source data file before importing. Sample 'prepared' data files are shown in Tables 8.1 and 8.2. Their contents are described in the Sections 8.6.4–8.6.8.

(iii) The *Import Wizard* is used to import the source file into an existing 'target' *CES* database. The procedure is described in Sections 8.6.9–8.6.11.

IDENTITY	PARENT	HASDATA	ISFOLDER	NAME	CODE	COLOUR	Account No	Products Supplied	Delivery	Batch size_1	Batch size_2
11		0	1	Computer	CP	1					
12		0	1	Transport	TR	2					
13		0	1	Projects	PJ	7					
14		0	1	Office	OF	4					
104	11	1	0	Monitor Co.	MC1	1	8754	"15,17 inch monitors"	TRUE	1	5
105	11	1	0	Ergo Keyboards	EK	10	4683	keyboards	TRUE	1	100
106	14	1	0	Stationary Inc	SI	4					

Table 8.1 Sample data file prepared for importing: illustrating the special fields

length{m}	max speed_1{{m}/{s}}	max speed_2{{m}/{s}}	type of craft{mode}	passengers	notes
3.1	3	4	ground	1	rarely used
108	7000	7700	air	0	high risk
1000	8	10	water	1	many types of load
60	900	1000	air		unknown type
37.5	70	80		0	

Table 8.2 Sample data file prepared for importing: illustrating units, discrete, and logical attributes.

8.6.4 Preparing for import: Data formats

File Structure

The import file can contain one or more data tables. Each row of each table is treated as a record. Each new record must begin on a new line. The columns (fields) are treated as data values.

Data in a *text* file is imported as a single table. The character acting as the text separator ('delimiter') must be either a comma ',' or a tab. If the delimiter is a comma, then the file extension must be '.txt' or '.csv'. If the delimiter is a tab, then the file extension must be '.tab'.

Table Names

The name of a table is taken from its name in the source file: the table names in a database, the 'sheet' names in a spreadsheet, or the name of a text file.

Field Names

Field names are taken from their names in the source database or the *first row* in a text file or spreadsheet. All field names must be unique within their table. There are a number of special field names which can be used also (see next section).

Record Names

Record names must be unique for their branch of the table tree. It is acceptable to have the same names on different branches, eg: Magnesium / *Cast* and Aluminium / *Cast*.

The attribute type, name, units and discrete types can be edited during the *Attribute Selection* stage of the *Import* Wizard (See Section 8.6.11).

8.6.5 Preparing for import: Naming fields

CES Constructor will import data 'as is' – but to get the most from your data it is best to prepare the data before importing. If you are importing from another Granta database then no preparation is necessary.

Naming Fields

Unlike ordinary databases, a Granta database distinguishes between record 'properties' and 'attributes'. Properties identify records within the database, which allows the records to be displayed on the screen (usually in a hierarchical format on the table tree). All records in a Granta database contain properties. Most records also contain attributes, but some, for example folder records, do not. The attributes are used for selection in *CES Selector*. Since ordinary databases do not have this distinction, importing data using *CES Constructor* relies on specially named fields in your database to distinguish between these two types of data (properties and attributes). The special fields are as follows (see Table 8.3):

- IDENTITY
- PARENT
- HASDATA
- ISFOLDER
- NAME
- CODE
- COLOUR
- LONGNAME

The imported records can be arranged into a tree structure using the special fields PARENT, ISFOLDER and CODE. COLOUR specifies the colour of the record icon on the tree (and on selection charts). NAME, LONGNAME and IDENTITY are used for various forms of identification. HASDATA specifies whether the record has attribute values or not. See the example in Table 8.1.

If your data contains any information that you would like to use in a special field then you should name that field in your database accordingly. For example, in a database of manufacturers you may have a field 'Company Name'. If you rename this file 'NAME' then the manufacturer's company name will be displayed on the *CES* table tree.

Similarly, if you have information with a field name corresponding to one of the special fields, but which should *not* be used as a special field by *Constructor* then these fields should be renamed. For example, in a database of parts you might have a field COLOUR that is used to hold the colour of a certain part. This might need to be renamed.

8.6.6 Preparing for Import: Special Fields

The operation and specifications of the special fields are summarised in Table 8.3.

Name	Description	Type	Default Value
IDENTITY	Used to uniquely identify each record, use this field together with the parent field to allow a hierarchical structure to be imported. For example, when importing a database of parts the 'PART NO.' field could be renamed to 'IDENTITY' to enable the part number to uniquely identify the part record during importing.	Number or Text	' '
PARENT	Used when importing a hierarchical structure this field refers to the identity (IDENTITY) of the record that is the parent of this record in the hierarchical structure. For example if you were to import a table of animals, then the parent record of the 'apes' record might be the 'mammals' record. This field should be the same type as the IDENTITY field. If this field is empty then *Constructor* places the record at the root level of the table tree.	Number or Text (same as IDENTITY)	' '
HASDATA	Used to distinguish between records with attribute data and records without attribute data. If this value is not set then no attribute data is imported for this record. Records with attribute data should have this value set to TRUE or 1.	Number (0/1) or Boolean (FALSE/TRUE)	1
ISFOLDER	Used when importing a hierarchical structure. Records used as folders should have this value set to TRUE or 1.	Number (0/1) or Boolean (FALSE/TRUE)	0
NAME	The name of the record as shown in the table tree. (Also referred to as the 'short name' or 'tree name' in the documentation.)	Text	Record (X)
CODE	A 'tree' code for the record.	Text (max 3 chars)	' '
COLOUR	The colour of a record is used to shade record icons in the *CES* tree and selection graphs. This allows the user to quickly identify record groupings. This integer field should be one of the following values. 0 Red 8 Navy 1 Lime 9 Olive 2 Blue 10 Purple 3 Yellow 11 Teal 4 Fuchsia 12 Grey 5 Aqua 13 Black 6 Maroon 14 White 7 Green 15 Silver	Number (0–15)	Fuchsia
LONGNAME	The full name of the record.	Text	Value from NAME

Table 8.3 Descriptions of the Special Fields

8.6.7 Preparing for Import: Units, Currency, Discrete Types

To import a *unit* for a numeric attribute, directly follow the field name with the unit symbol enclosed in curly brackets or braces, as shown in Table 8.2. For example 'length{m}' specifies an attribute of name 'length' and units 'm'. If the unit symbol does not already exist in the database, a new unit will be created. Only numeric attributes can have units.

It is also possible to import a unit equation using nested brackets and the operators '*, / and ^'. For example, 'max_speed{{m}/{s}}' specifies an attribute of name 'max speed' and units 'm' per 's' (see Table 8.2).

To import *discrete* data, directly follow the field name with the name of the discrete type enclosed in curly brackets or braces, e.g. 'type of craft{mode}' specifies an attribute of name 'type of craft' and its discrete type 'mode' (Table 8.2). A new Discrete Type for the attribute will be created in the database with discrete values corresponding to the data values listed in the table ('ground', 'air' and 'water' in Table 8.2). If no name is specified for the Discrete Type when a new discrete attribute is imported, its Discrete Type will be given the same name as the attribute.

Units and discrete types can only be imported into a database when they accompany an attribute. They cannot be imported any other way.

To import a *currency* unit for a numeric attribute, enclose the currency symbol in angled brackets inside curly braces. For example, 'flat fee{<USD>}' specifies an attribute of name 'flat fee' and currency unit 'USD' (US Dollars). The currency must already exist in the database. Look at a list of available currencies in *Database Properties* dialog or *Options* dialog, to discover the correct three-letter code to specify.

8.6.8 Preparing for Import: Attribute Data Values

The naming conventions and limits on data types listed in Appendix C2 and C3 hold for imported data.

Floating Point Data

Data values must be numbers, with a maximum of six significant figures. Point data occupies one field (eg 'Account No' in Table 8.1). Range data occupies two fields, (eg 'max_speed_1' and 'max_speed_2' in Table 8.2). The two fields are identified as belonging to the same range attribute during the importing process (Section 8.6.10).

Numbers can be entered as integers '456', decimals '123.456' or formatted with an exponent '456e+010' or '123.456e+009'.

Numeric data values are stored as single precision floating point numbers and must have values within the ranges:

–1e+038 to –1e-039 for negative numbers

1e-039 to 1e+038 for positive numbers.

Integer Data

Data values are a number, with a maximum of ten significant figures. Integer data occupies one field. Integer data cannot be assigned a unit.

Data values are entered as an integer e.g. 456.

Data values are stored as long integer numbers and should range in value from:

-2,147,483,648 to 2,147,483,647

Discrete Data

Discrete data values are text, e.g. the value '1' will be treated as the character '1', not the number '1.0'. A discrete attribute cannot be assigned a unit, instead a Discrete Type is created for it. The data values become Discrete Values for the Discrete Type. A maximum of 26 different discrete values is allowed.

Logical data

Data values can be a number (1 or 0) or a Boolean (TRUE or FALSE). No units can be assigned to logical data.

Short Text

A maximum of 40 characters is allowed. No units can be assigned to short text data.

Long Text

A maximum of 64k characters is allowed. No units can be assigned to long text data.

In the case of a text string in tab or comma delimited text file: if the text string contains the delimiter, (eg a comma ','), then quote marks (" ") should be put around the entire text string. For example "15,17 inch monitors" in Table 8.1.

Blanks

An Attribute data value can also be left blank. In *Constructor* blank numeric fields are assumed to have no value, and in *Selector*, the value of 'Not Applicable'.

Link Data

It is not possible to import Link data, even from a Granta Database.

Picture Data

It is not possible to import Picture data that is contained in another database. The only exception to this is importing a table in a Granta Database where records in the table have a picture assigned to them. Individual picture files can be imported using the *Picture Gallery*.

Dates

Data values can be entered in a valid short or long date system format e.g.

dd/MM/yyyy	22/09/00
d.M.yy	22.09.2000
yyyy-MM-dd	2000-09-22
M/d/yyyy	9/22/2000
dd mmmm yyyy	22 September 2000

Data values can range from: January 1, 100 to December 31, 9999

Hyperlinks

Data values are valid URLs, consisting of a protocol and location as Long Text.

e.g. http://www.grantadesign.com

Functional data

Functional attributes cannot be imported by *CES 3.2*.

8.6.9 Importing Data: Select the Data Source

Importing is carried out using the *Importing Wizard.* To start importing a table into an existing database

Select *Import* from the *File* menu (File/Import).

The wizard will guide you through the importing process as outlined below. Some of the steps may be omitted by the wizard, depending on the contents of your source file.

Constructor can import data from a number of different database formats. First select the file type from the list. Then use the Browse button to locate the database , or type directly into the input field.

eg Select the sample Excel Spreadsheet file:
C:\Program Files\CES Selector 3.2\Samples\Database\company2.xls

Note that some database types may require a 'connection string' to be entered into the input field.

8.6.10 Importing Data: Select the Tables

If your source database contains more than one table you will be asked which tables you wish to import, as in figure 8.24.

Select one or more tables by clicking on the check boxes

8.6.11 Importing Data: Specify the Attributes for Each Table

You will be asked which fields you wish to import as attributes. Adding or removing a tick in the check box selects or de–selects the field (figure 8.25).

If the source table contains 'special' fields, the program will automatically use this information to perform the control functions specified in section 8.6.6. If you select the field for import (ie check its box in the wizard) it will also appear as an attribute in the table (eg 'NAME' in figure 8.25).

Select the fields you would like to appear in the new table

For each field, the *Import Wizard* attempts to determine the best settings for the attribute type; attribute name; and units or discrete type. If you wish to alter these settings, select the attribute name and enter the new settings in the 'Import field into database as' section (figure 8.26).

To convert two numeric properties to a range attribute, hold down the 'control' key and select both attributes from the left window pane. Then select the attribute type 'range' and specify the name and units in the edit boxes.

Edit the attribute types, names and units as necessary

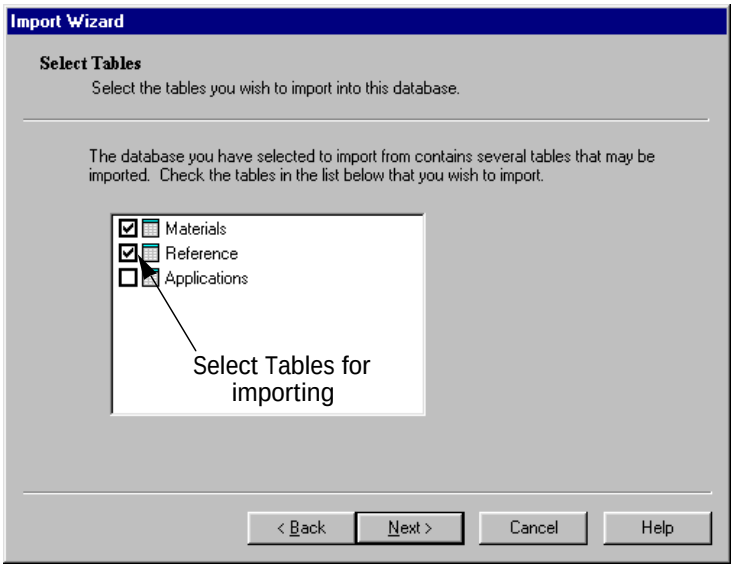
Import Wizard
Select Tables
Select the tables you wish to import into this database.
The database you have selected to import from contains several tables that may be imported. Check the tables in the list below that you wish to import.
Materials
Reference
Applications
Select Tables for importing
< Back
Next >
Cancel
Help

Fig. 8.24 Selecting tables for importing in the *Import Wizard*.

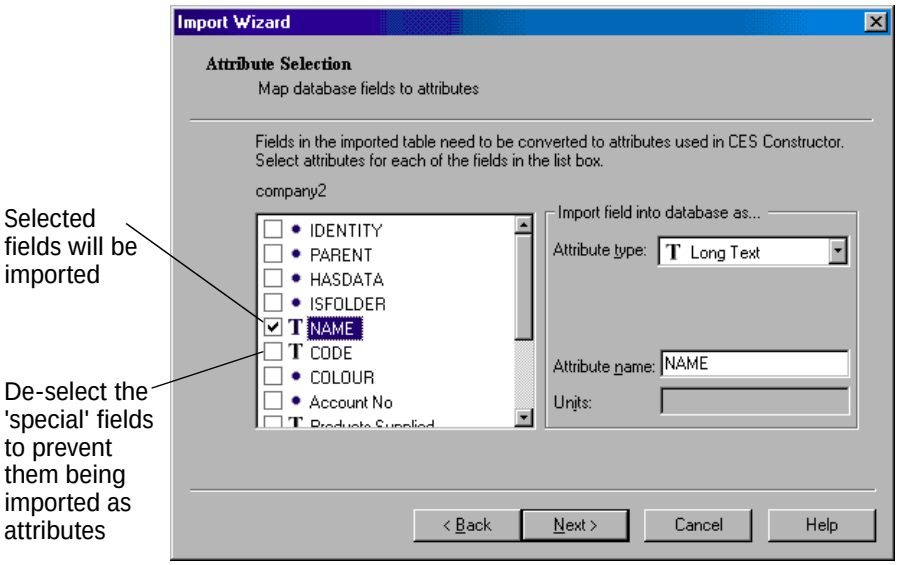

Fig. 8.25 Selecting attributes for importing in the *Import Wizard*.

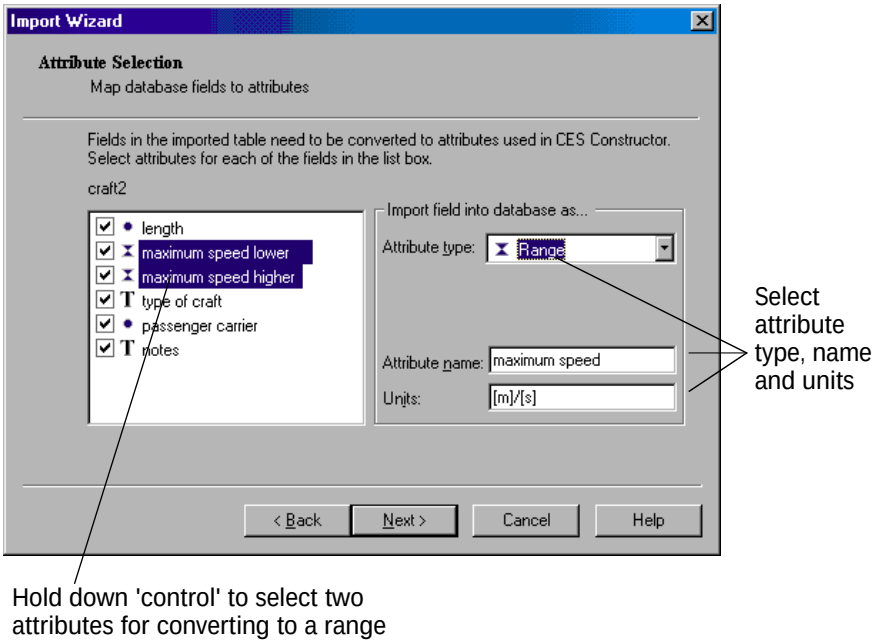

Fig. 8.26 Importing range attributes in the Import Wizard.

When you have finished selecting the attributes for importing:

Click on *Next >*, to complete the import process.

Your data will be imported (see figure 8.27). Any errors that occur, eg due to duplicate names, will be reported before the process finishes.

8.7 Copying and Updating Data Records

8.7.1 Simple and Advanced Copying of a Table

A simple copy and paste of a table will create an exact duplicate of the table in the database, that is the properties, attributes, tree structure and attribute data in the table will duplicated.

A more advanced copy and paste of a table can be performed by using the **Paste Special** command on the *Edit* menu. This gives the option of copying the table 'through' a form and filter selected by the user. Only records in the selected filter will be included in the destination table. Only attributes and the data for attributes in the selected form will be included in the destination table.

If there are no user–defined filters then the table is copied through the default filter <All Records> and default form <All Alphabetical>. This copies the entire table and is the equivalent of using the basic **Paste** command.

Procedure:

Select the name of the table to be copied on the *Database* tab of the *Control* window.

Select 'Copy Table' from the *Edit* menu.

Select 'Paste Special' from the *Edit* menu.

The *Paste Special* dialog will appear, enabling the user to specify the name of the new table and the filter and form through which the table will be copied.

Click OK to perform the copy.

A new table will appear on the list of tables on the Database page of the *Control* window.

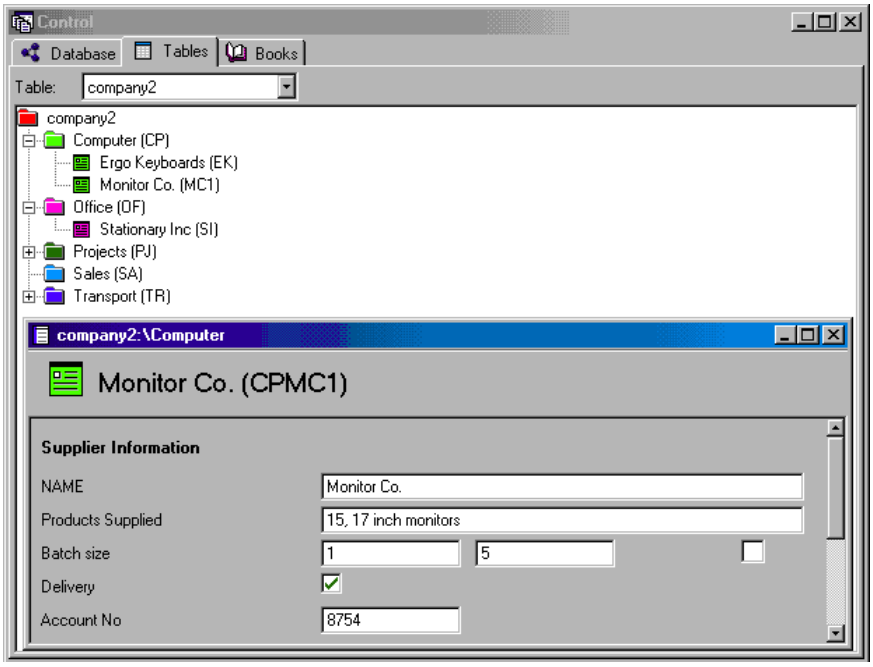

Fig. 8.27 The result of importing the information shown in Table 8.1. Compare the table tree information (branch names, codes, etc) with the special fields in the source file.

8.7.2 Copying Data Values Down a Branch

Once a tree structure is in place, it is possible to copy attribute data values in a selected data (generic) record to all child records on the branch below the selected record.

The user can select:

(i) the attributes whose values are to be copied;

(ii) whether existing values should be left or overwritten;

(iii) whether the values should be pasted into all child records, or only those records in the current filter.

Procedure:

Select the data (generic) record with the values of interest.

Select 'Copy Record' on the *Edit* menu.

Select 'Copy down branch' on the *Edit* menu.

The *Copy down branch* dialog appears.

Check the boxes for those attributes whose values are to be copied down the branch.

If you wish to 'Overwrite existing values', enable the appropriate box.

If you wish to 'Copy only to records in the current filter', enable the appropriate box.

Click OK to perform the operation or Cancel.

8.7.3 Copying and Merging Records

Records can be copied and pasted between different locations on the same table or from one table to another. A specific record can be copied, or a whole branch, i.e. a folder or generic record and all its child records. The record(s) are either copied or merged, depending on the *name* of the record it is pasted to.

If the short name (tree name) of the record being copied (source record) matches a record under the destination branch, then a dialog will give the options to:

(i) merge records and backup destination: a copy is taken of the destination record before the merge operation is performed (see below for information on how merge affects the destination record);

(ii) merge records without backup: the records are merged together (see below for details);

(iii) replace existing record(s): the existing record is deleted before the source record is copied over.

If the short names of the records do not match, then a straightforward copy takes place.

The effects of the merge operation on the destination records depend on the attributes being merged. They are listed in Table 8.4.

Record Property	Action
LONG NAME	Overwritten by source record
COLOUR	Overwritten by source record
SHORT CODE	Overwritten by source record
ISFOLDER	Destination record becomes a folder if the source record is a folder
HAS ATTRIBUTES	Destination record gains attribute if the source record has attributes
FILTERS	If the source record is in a filter, then the destination record is added to the filter
LINKS	The destination record gains any links that the source record has, as well as keeping its own
DATA	If any attribute has the value 'Not Applicable' in the destination record, then it is overwritten by the data in the source record
CHILDREN	All the children of the source record are merged onto the branch

Table 8.4 Effect of merge operation on destination records.

When copying records between tables, if the properties of the table of the source record do not match the properties of the destination table, then a dialog will appear giving the option to edit the properties of the destination table so that they match the source.

Procedure:

Select the record of interest (if the record is a generic or folder record all the child records will be included).

Select 'Copy Record' from the *Edit* menu.

Select the record under which the copied records are to appear i.e. select the parent record for the destination record(s).

Select 'Paste' from the *Edit* menu.

If the short name (tree name) of the record being copied (source record) matches a record under the destination branch, then the *Record Paste* dialog opens.

Select a merge operation.

Click OK to paste the records or Cancel.

When copying records between tables, if the table properties of the source and destination table do not match, the option to edit the destination table properties will be offered.

8.7.4 Copying Records Between Tables

When records are copied between tables, and the properties of the table of the source record do not match the properties of the destination table, a dialog will appear giving an option to edit the properties of the destination table (attributes, filters, forms and related tables) so that they match the source.

Attributes

If the source table and the destination table contain matching attributes i.e. attributes of the same *name, type and units*, then the data is copied between tables without any need for intervention. If the attributes differ only by units, and the units are related e.g. the source table attribute is in MPa and the destination table attribute is in GPa, then the data will automatically be converted to the destination unit.

If an attribute exists in the source table, but not the destination table, then an additional attribute in the destination table can be created.

If an attribute exists in the source table, and an attribute of the same name but of a different type or with units that cannot be converted between the two, exists in the destination table, then a new attribute with a different name can be created in the destination table to hold the same data as the source. The user will be informed that this has occurred.

If you choose not to create new or additional attributes in the destination table, then the data values for the attributes will be lost from the copied records.

Filters

If the source table and the destination table contain filters of the same name, then the copied records will be added to the same filters in the destination table without any need for intervention.

If a filter exists in the source table, but not the destination table, then an additional filter in the destination table can be created.

In the destination table, if appropriate, the copied records and its parent records will be added to this additional filter. No other records will be added to the filter. If you choose not to create additional filters, then filter information will be lost from the copied records.

Forms

If the source table and the destination table contain matching identical forms, then there is no need for the creation of an additional form.

If a form exists in the source table, but not the destination table, then an additional form in the destination table can be created.

If a form exists in the source table, and a form of the same name but with different headings or different attributes exists in the destination table, then a new form with a different name can be created in the destination table to hold the same layout as the source.

If you choose not to create additional forms, then form information will be lost in the destination table.

Related Tables

If a relationship exists between the source table and 'third-party' table, but not between the destination table and this 'third-party' table, then one will be created. Any existing relationships will not be affected.

If you choose not to create the relationships, then link information i.e. linked records will be lost in the destination table.

Notes

Pre-existing empty forms and filters will be copied. However, if a form becomes empty during the copying process as a result of the Attributes resolutions, then it will not be copied.

Procedure:

Select the record of interest on the source table (if the record is a generic or folder record all its child records will include be included).

Select 'Copy Record' from the *Edit* menu.

Switch to the destination table.

Select the record under which the copied records are to appear i.e. select the parent record for the destination record(s).

Select 'Paste' from the *Edit* menu.

If the short name of the selected record matches an existing record on the destination branch, the option to merge records will be offered.

The *Copying records between tables* dialog will appear.

Enable or disable the resolutions as required.

Click OK to paste the records or Cancel.

8.7.5 Updating an Edited CES 3.1 Database

The *Update Database* Wizard is designed to take a user–edited *CES 3.1* database and update it to match the *CES 3.2* database so that the Granta created records are updated and the user created records are unchanged.

The current database should be backed up before the update is started.

The user has the ability to match Tables, Attributes and Records. Essentially, in each case there are two options:

(i) To create items in the current database to match the external database.

(ii) To delete items in the current database to match the external database.

The current database is the edited 3.1 database, and the external database is the 3.2 database. For each option, the user can accept the default actions or set a custom action.

Update Tables

If the names of tables in the two databases do not match, this option gives the ability to match them.

The *default settings* are to create all tables necessary and to delete no tables in the current database.

Synchronise Attributes

If the names of tables in the two databases match, this option gives the ability to match the attributes in these tables.

The *default settings* are to create all attributes necessary and to delete no attributes in the current database.

Attributes that have the same name but differ by their units, data type or assigned parameters will be considered a mismatch and therefore available for synchronisation.

Synchronise Records

If the names of tables in the two databases match, this option gives the ability to match the records in these tables.

The *default settings* are to create all Granta records necessary; to delete all Granta records necessary; *not* to delete any *user* records in the current database; and to overwrite all existing Granta records with updated values.

Branches that have only changed location on the tree will not be considered.

Start Update

During the updating process, the default action is for records created by Granta in the current database to be overwritten with new data from the external database. Records created by the user will be unchanged.

Where there is a conflict between a user created record and a new Granta record, both records will be present in the updated database.

See the Reference Guide on the Update Database Wizard in the on-line Help, for further information.

8.8 Conclusions

CES Constructor is a sophisticated tool for making selection databases. To take full advantage of its capabilities, we recommend that you work through the Tutorials in the on-line *Help* system.

The expert staff at Granta Design can provide advice on database design issues, and can provide a consulting service to help with major database development projects.

Granta Design would welcome your feedback on any improvements you would like to see in the *CES* system, its data or documentation (email: support@grantadesign.com).

APPENDICES

Appendix A – Toolbars

A1 Selector

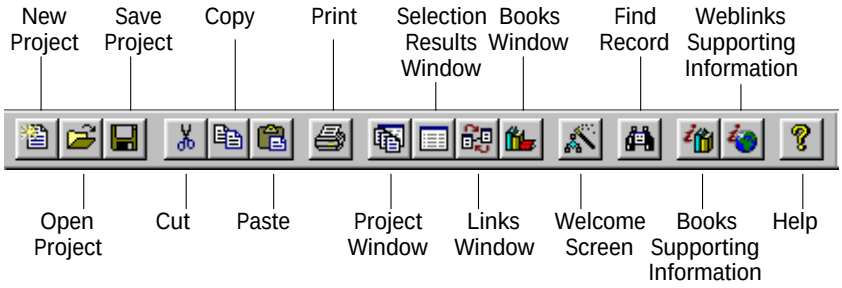

Fig. A1 The Standard toolbar in Selector

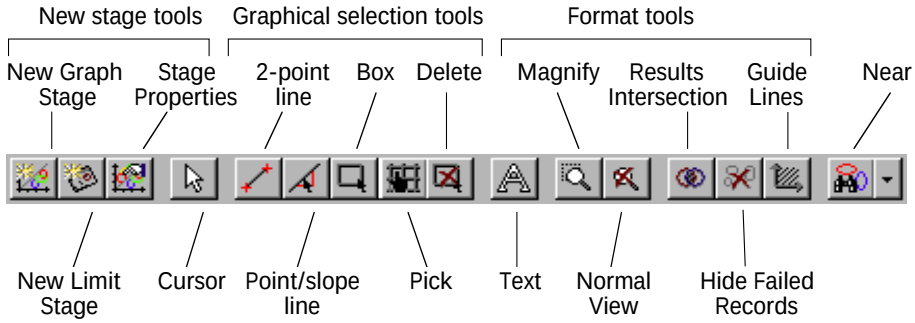

Fig. A2 The Project toolbar in Selector

A2 Selector and Constructor

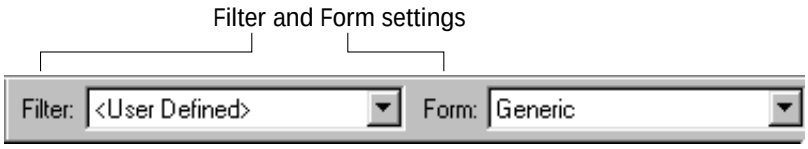

Fig. A3 The Filters toolbar for the *Selection Table* in Selector and the *Current table* in Constructor.

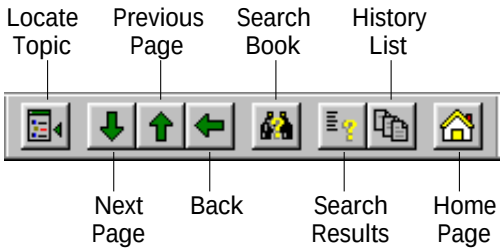

Fig. A4 The Books toolbar in Selector and Constructor

A3 Constructor

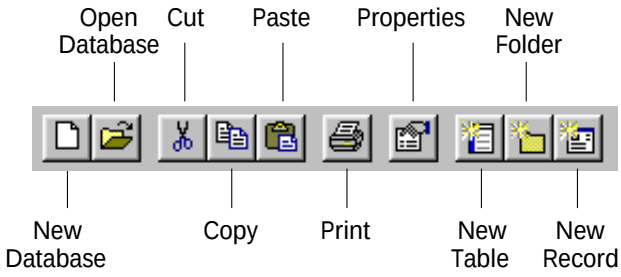

Fig. A5 First half of the Standard toolbar in Constructor

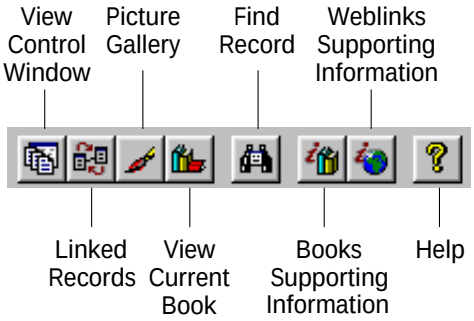

Fig. A6 Second half of the Standard toolbar in Constructor

Appendix B – Filter Settings for Selection

The following combination of settings for the Selection Table and filter are recommended when performing a selection. Other settings may give incorrect selection results.

B1 Materials Selection

Selection Table Materials

Materials filter: All Bulk Materials

Process filter: Generic

Shape filter: Shape Class

B2 Process Selection

Selection Table Process

Materials filter: All Bulk Materials

Process filter: Generic

Shape filter: Shape Class

B3 Structural Sections Selection

Selection Table Structural Sections

Materials filter: All Bulk Materials

Process filter: Generic

Shape filter: Structural Sections

Structural Sections filter: Structural Sections

It is also recommended that the matching form for a filter be used when viewing records. The exception to this is the 'Generic' form for materials, which can be used in conjunction with any of the material class filters e.g. Ceramic, Foam etc.

For more information on the data modules, and the filters and forms available with each, please see the relevant sections of *CES InDepth*.

Appendix C – General Information

C1 File Types

Projects

*.gdb	Granta Database file
*.ces	Selector Project file (text)

On-line Books

*.gmv	Granta MediaView file
*.cdb	Granta Contents Database file

Currency File

currency.csv

Picture Files (for importing into Picture Gallery)

*.bmp	Bitmap
*.emf	Enhanced metafile
*.wmf	Windows metafile

Constructor Import File Types

*.mdb	Microsoft Access 97 Database
*.dbf	DBase III, IV and V Database
*.gdb	Granta Database
*.xls	Microsoft Excel Spreadsheet
*.txt, *.csv, *.tab	Text File (Comma separated and tab delimited formats)

C2 Limits on Data Types

CES Symbol / Data Type	Limit
Numerical Range Point Functional Range Functional Point	A maximum of 6 significant figures. Data values can be entered as: • an integer e.g. 456 • a decimal e.g. 123.456, -0.000123456 • or formatted with an exponent e.g. 456e+010 or 123.456e+009 Data values can range from: –1e+038 to –1e-039 for negative values 1e-039 to 1e+038 for positive values.
Numerical Integer	A maximum of 10 significant figures. Data values are entered as an integer e.g. 456 Data values can range from: -2,147,483,648 to 2,147,483,647
Logical	TRUE or FALSE
Discrete	A maximum of 26 values in a set e.g. Red, Orange, Yellow; or A, B, C, ..., X, Y, Z
Date	Data values can be entered in a valid short or long date system format e.g. dd/MM/yyyy 22/09/00 d.M.yy 22.09.2000 yyyy-MM-dd 2000-09-22 M/d/yyyy 9/22/2000 dd mmmm yyyy 22 September 2000 Data values can range from: January 1, 100 to December 31, 9999
Picture	Windows Bitmap (*.bmp); Enhanced Metafile (*.emf); Windows Metafile (*. wmf)
Short Text	40 characters
Long Text	64K
Hyperlink	Data values are valid URLs, consisting of a protocol and location e.g. http://www.grantadesign.com as Long Text
Expression	as Long Text

C3 Naming Conventions

Names are case sensitive and must be unique.

	Maximum number of characters in name	Invalid Characters cannot contain	Cannot start with	Cannot be
Database				
Database Title	255			
Author	255			
Company	255			
Notes	255			
Unit				
Unit Name	60			blank
Unit Symbol	60	[ ]		blank
Unit Equation	255			blank
Unit System	60			blank
Discrete				
Discrete Type Name	60	[ ]		blank
Discrete Value Name	60	[ ]		blank
Constant				
Constant Name	60	[ ] :		blank
Parameter				
Parameter Name	60	[ ] :		blank
Picture Gallery				
Picture Name	60			blank
Picture Group Name	60			blank
Table				
Table Name	255	[ ] \ .		blank
Table Type	255			
Filter Name	64	[ ] ! ` .	space	blank
Form Name	255			blank
Form Heading	80			blank
Equation Name	60	[ ] :	` space	blank
Attribute Name	60	[ ] :	` space	blank, "Record Identity"
Record				
Short Name	255	[ ] \ ! `		blank
Full Name	255			blank
Short Code	3			

C4 Constructor Options for Preferred Currency and Units

For the Current Database

Settings	Database Options	
	Preferred Currency	**Preferred Unit System**
<Automatic>	The Regional Setting from the operating system for currency is used to view data. The regional setting is specified after 'Automatic' e.g. <Automatic - GBP>.	The Regional Setting from the operating system for unit system is used to view data. The regional setting is specified after 'Automatic' e.g. '<Automatic - Metric>'.
<None>	Data is displayed using the units stored in the database. Currency data is displayed using the default Currency (see *Database Properties* dialog).	Data is displaying using the units stored in the database. Attribute data is displayed using the unit for the attribute definition (see *Table Properties* dialog).
Named Setting	Named currency is used to display data e.g. 'US Dollar (USD)'.	Named unit system is used to display data e.g. 'Metric'.

For New Databases

Settings	Database Options	
	Preferred Currency	**Preferred Unit System**
<Automatic>	The new database is created with its currency unit as the Regional Setting of the operating system. The regional setting is specified after 'Automatic' e.g. <Automatic - GBP>'.	The new database is created with its unit system as the Regional Setting of the operating system. The regional setting is specified after 'Automatic' e.g. <Automatic - Metric>'.
<None>	The new database is created with the currency unit as the Regional Setting.	The new database is created with no unit system.
Named Setting	The new database is created with the named currency as the currency unit e.g. 'Australian Dollar (AUD)'.	The new database is created with the named unit system as the unit system e.g. 'SI'

Appendix D – Functional Data Syntax

D1 Description of Functional Data Syntax

Numerical data can be stored as a functional range or a functional point attribute. A functional attribute consists of one or more functions. Each function defines how the attribute value varies dependent on one or more parameters in an exclusive domain.

A function is stored as a numeric expression (type 'Expression') or a set of points (type 'Array').

Both types of function are entered in *CES* in similar formats.

Description:
Type:
Parameters:
Value:

Description is a textual description of the domain.

Type defines the type of function (Expression or Array) and indicates an estimated value.

Parameters lists those parameters in the function; and for Expression functions, the domain of the parameter for which the function is valid. There is no limit on the number of parameters with which a functional attribute is allowed to vary, but 10 is a practical limit.

Value defines how the attribute varies dependent on the parameters. *Expression* value functions take the form of a numerical expression. *Array* value functions specify of a set of points, and the type of interpolation between points.

A functional attribute may have a parameter assigned to it that is not listed in 'Parameters'. However, if a parameter is listed in 'Parameters', it must be assigned to the attribute.

D2 Expression Function

A function stored as an expression must specify

Type: Expression

Then it must list all parameters used in the expression and the range over which that parameter is valid. The units are assumed to be the parameters' current units.

Parameters: ([Parameter Name] = lower limit : upper limit)

The Value is the instruction on how to calculate the attribute data value, in the form of an expression. The format for the expression is the normal format used for *CES* expressions e.g.

Value: [parameter] * [range attribute]

If a parameter is not valid, or not assigned to the attribute, or if the expression is invalid, *Constructor* will display an error message.

Example

Functional Range attribute 'F1', one Parameter 'B1', one function Type 'Expression'

Description: Domain
Type: Expression
Parameters: ([B1]=1:10)
Value: [Parameter:B1]^2*[R1]

Notes

The numerical data types available in *CES 3.2* are range, point, functional range, functional point and integer.

A numerical expression can consist of the following terms: range, point, functional range, functional point, integer, parameter and constant.

The logarithm function (base 10 or base e) can be applied to a valid component or numerical expression e.g. log([Attribute]) or ln(numerical expression).

It is possible to use a range attribute in the expression for a functional point attribute.

It is possible to use a point attribute in the expression for a functional range attribute.

D3 Array Function

A function stored as a set of points must specify

Type: Array

It must list all parameters used in the array

Parameters: ([Parameter Name 1], [Parameter Name 2])

It is also optional to put 'lin' or 'log' after the list of parameters, if it is omitted, it defaults to 'log' (See below for explanation.)

Parameters: ([Parameter Name 1], [Parameter Name 2], lin)

The Value is the set of points in the form of an array. For each point, the parameters are listed in the order defined above (in Parameters), followed by the result (the value of the functional attribute). If the attribute is a functional range attribute, a colon is used to specify the limits of the range.

Value: (point 1) (point 2)

where point 1 = (value of parameter 1, value of parameter 2, result lower limit : result upper limit) for a functional range attribute.

where point 1 = (value of parameter 1, value of parameter 2, result) for a functional point attribute.

A multi-dimensional linear interpolator will interpolate a result for any parameter values within the domain limits.

If the interpolator for a parameter is set to 'lin', it will perform a linear interpolation on a linear scale between data points for the parameter. If the interpolator for a parameter is set to 'log', it will perform a linear interpolation on a logarithmic scale. This is set on the Parameters page of the *Database Properties* dialog in *Constructor.*

If the parameter list in the Array function is suffixed with 'lin', it will perform a linear interpolation on a linear scale between data points for the result (otherwise the interpolation will take the default setting of linear on a logarithmic scale).

When interpolation is carried out, it is necessary to provide enough data points for the attribute to make the interpolation accurate.

If the parameter is not valid, if there is the wrong number of values in a point, or if a range value is specified, *Constructor* will display an error message.

Example

Functional Range attribute 'F2', one Parameter 'B1', one function Type 'Array'

Description: Domain
Type: Array
Parameters: ([B1])
Value: (12, 53:59)(20, 78:80)(30, 90:100)

D4 Estimated Functional Attribute

To mark a functional attribute as 'estimated', put '(e)' or '(estimate)' or '*' after stating the 'Type' e.g.

Type: Expression (estimate)

When a data value from a domain marked as an estimate is displayed, *CES Selector* will indicate this with an asterisk '*'.

D5 Functional Range Examples

Functional Range Attribute 'F1', one Parameter 'B1', one function Type 'Expression'

Description: Domain
Type: Expression
Parameters: ([B1]=1:10)
Value: [Parameter:B1]^2*[R1]

where 'B1' is the parameter assigned to the functional attribute 'F1', the default value of 'B1' is 10 and 'R1' is a Range attribute, value 56–89.

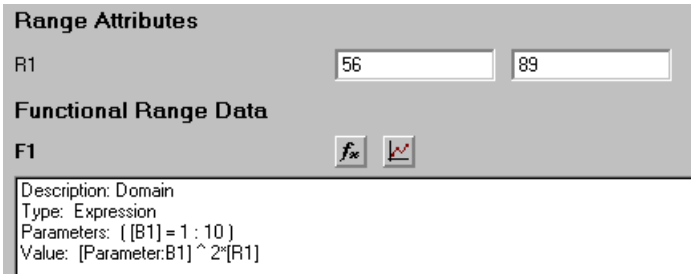

Fig. D1 Part of record showing functional data for 'F1'

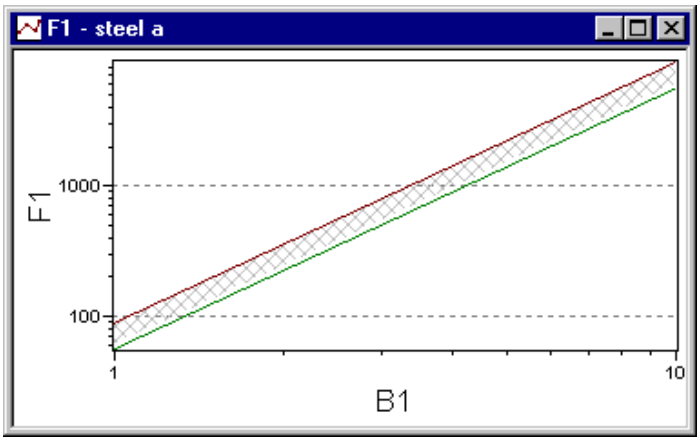

Fig. D2 Graph of functional range attribute 'F1' displayed on log scales

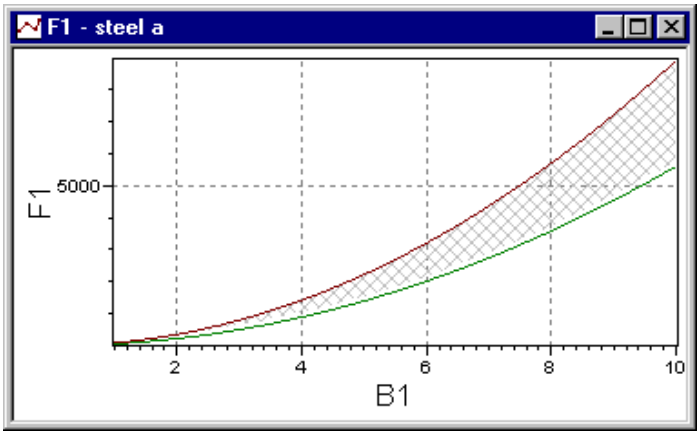

Fig. D3 Graph of functional range attribute 'F1' displayed on linear scales

Functional Range Attribute 'F2', one Parameter 'B1', one function Type 'Array'

Description: Domain
Type: Array
Parameters: ([B1])
Value: (12, 53:59)(20, 78:80)(30, 90:100)

where 'B1' is the parameter assigned to the functional attribute 'F2' and the default value of 'B1' is 10. Interpolation on a log scale has been used between points.

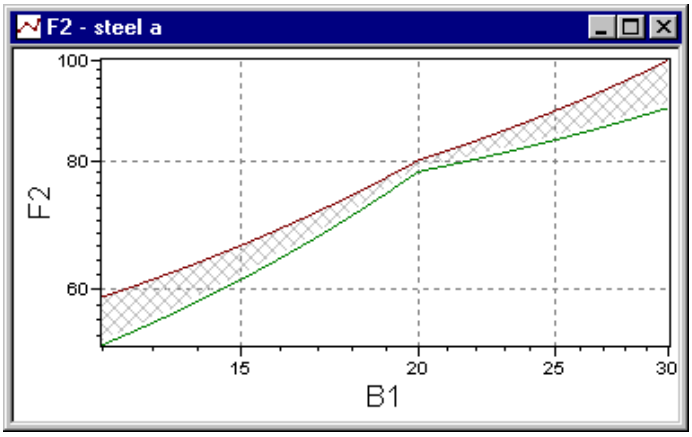

Fig. D4 Graph of functional range attribute 'F2' displayed on log scales

CES Example: Functional Range Attribute 'Fatigue Strength Model', two Parameters 'No. of Cycles' and 'Stress Ratio', one function Type 'Expression'

In *Constructor*, open the *CES* database (data.gdb), and set the filter and form of the Materials table to 'Metal'. View the metal record 'AerMet 100', under 'Metal\Ferrous Alloys\High Alloy Steels'.

D6 Functional Point Examples

Functional Point Attribute 'F3', one Parameter 'B1', one function Type 'Expression'

Description: Domain
Type: Expression
Parameters: ([B1] = 1 : 10)
Value: [Parameter:B1] * [P1]

where 'B1' is the parameter assigned to the functional attribute 'F3', the default value of 'B1' is 10 and 'P1' is a Point attribute, value 100.

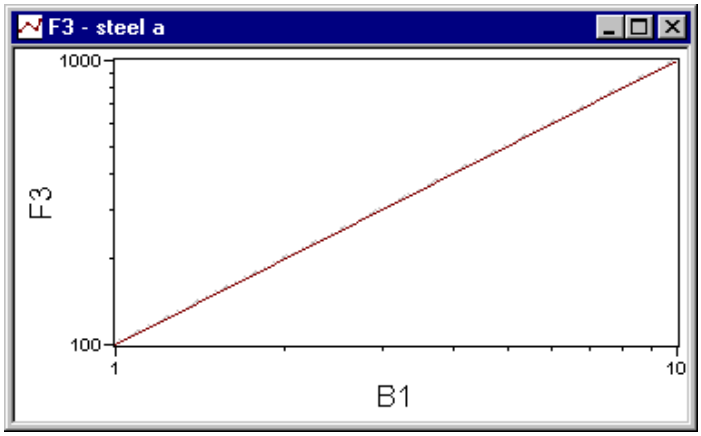

Fig. D5 Graph of functional point attribute 'F3' displayed on log scales

Functional Point Attribute 'F4', one Parameter 'B1', one function Type 'Array'

Description: Domain
Type: Array
Parameters: ([B1])
Value: (12, 53)(20, 80)(30, 90)

where 'B1' is the parameter assigned to the functional attribute 'F4', and the default value of 'B1' is 10.

Interpolation on a linear scale has been used between parameter values. Interpolation on a log scale has been used for the result.

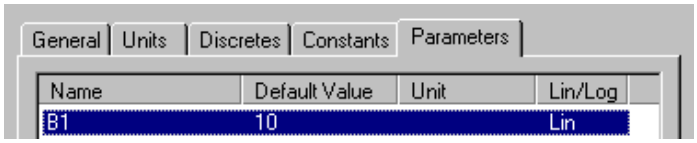

Fig. D6 Part of the Database Properties dialog showing parameter 'B1'

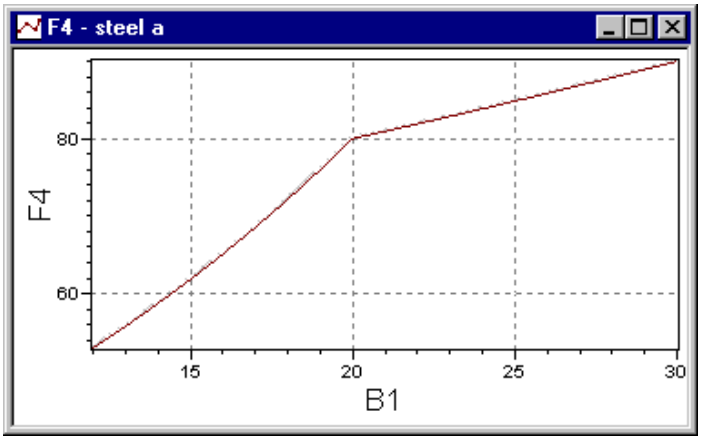

Fig. D7 Graph of functional point attribute 'F4' displayed on linear scales

D7 Example Files

Two example files for functional data of type Array are installed with the tutorial databases.

The spreadsheet 'function1.xls' is a Microsoft Excel 97 file, containing data points for a functional range attribute dependent on one parameter. Each row represents a data point, except for the first row, which names the columns. The first column is the minimum value of the functional attribute. The second column is the maximum value of the attribute. The third column is the value of the parameter.

	A	B	C
1	Strength (min)	Strength (max)	Temperature (K)
2	36	42	298
3	37	43	301
4	36	40	304
5	39	42	307

The text file 'function2.txt' shows these data points in a form valid for *Constructor*, the data can be pasted directly into the record attribute.

```
Description: Domain 1
Type:  Array
Parameters:  ( [Parameter:Temperature] , Lin )
Value:(298,36:42)(301,37:43)(304,36:40)(307,39:42)(3
```

Granta Design Limited provides a Microsoft Visual Basic macro in the 'User Area' of its web site, that converts functional data in an Excel spreadsheet from the form shown above to one valid for *Constructor.* Only Microsoft Excel is supported at present. Full instructions are given on the web site.

See: http://www.grantadesign.com/members/updates/functionaldatahelper.htm.

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